Kennelly Notebook #3

This notebook covers the period February-November 1890. It contains transcriptions by Arthur E. Kennelly of material from the rough record books used by experimenters in the Galvanometer Room. There are notes, drawings, tables, and calculations regarding a variety of electrical experiments, including tests of meters, batteries, induction coils, the magnetic permeability of iron, the carrying capacity of copper wire, and the production of copper by electrolysis. In addition, there are notes and design drawings of electric railway motors, including experiments conducted at the Edison General Electric works at Schenectady, and of low-horsepower motors for fans, dental equipment, and the phonograph. Also included are notes regarding 3-wire electric power systems, lighting plans for the Lick Observatory, tests comparing a Westinghouse and an experimental Edison transformer, and theoretical notes concerning physics, electricity, and mathematics. Among the experimenters whose work appears in this book are Jonas W. Aylsworth, Reginald Fessenden, and Alfred J. Thompson. At the end of the book is a subject index (filmed at the beginning of the book). The front cover is marked "III" and "1890." The book contains 160 numbered pages. Some pages were removed before the book was paginated. Graphs, blueprints, and other items have been pasted into the book.

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E5931-3

No. III.

Record Book

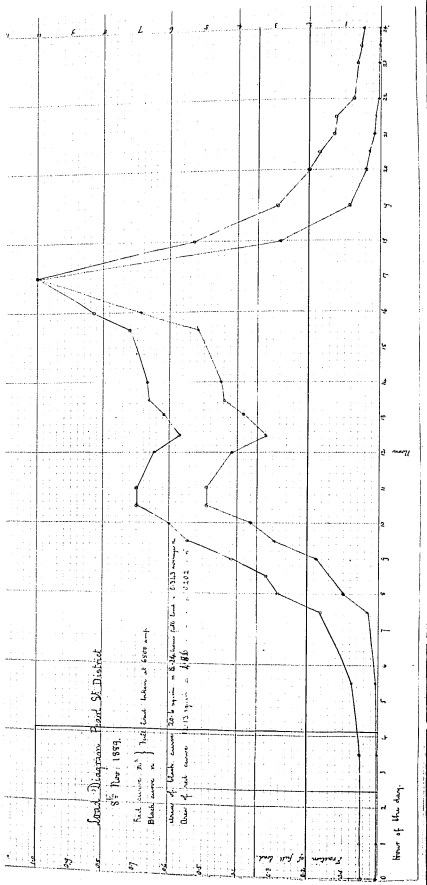
of

Observations, Measurements, Calculations and Data

compiled at the Edison Laboratory)

Orange N.J.

From 25th February 1890
to 3rd November 1890



On the economic transmission of power by single main feeders from Canal St to Fulton St New York, for the supply of 20,000 lamps.

First approximation. 25th Feby. 1890.

The distance being 4200 feet, on 3 wire system with the Edison composition lamp, the weight of copper at 15% drop will be about 244,000 lbs see preceding Record Book, p. 155. The cost of this annually at 20 ¢ per lb and 8% interest will be $3900.

The power to be delivered is $\frac{20000}{18}$ = 1110 HP. at full load and at 15% drop in feeders, the commercial efficiency of the system will be about 0.72 so that the H.P. lost in the feeders at full load = 1540 × 0.9 × 0.15 = 208. From the curve on the opposite page integrated by planimeter it appears that the average feeder loss is for this district 0.2 of the full load loss = 41.6 HP. At the estimated price of $50 per HP per annum this will represent $2080.

If the drop be made 20% the approximate yearly cost of copper (only) will be $2925, and the HP. lost will be approximately increased to $2800, making the loss 56 HP. on the average or 280 HP. at full load. The copper (only) in the feeder would be roughly $\frac{244,000}{4} \times 3$ = 183,000 lbs or $36,600

Test of a sample of specially prepared Rosin for Messrs Bergmann & Co. N.Y.

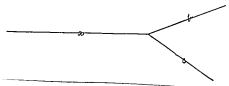
The sample differs distinctly from that previously furnished under the same, for test see preceding book. It is not nearly so non-inflammable being capable of supporting a flame when the substance is previously warmed. It is strong and takes a good thread also polishing well. Samples were set aside under seal.

Brief Account of Physiological Experiments made by H. P. Brown at the Edison Station in Columbus O.

March 8th 1890.

A calf had its hair clipped on the forehead and right side. Felt electrodes backed by copper plates and soaked in 5% NaHO solution were applied to these parts, and secured with cord. A current from the Siemens alternating Dynamo was applied at P.D. of 700 volts. 1600 revs per min = $\frac{8 \times 1600}{2 \times 60}$ = 106 ~ per sec. In falling to the ground the calf disengaged wire from forehead electrode thus not taking more than some two seconds of current. Calf struggled slightly but totally hint. Application renewed for 15 seconds or 15 seconds.

A horse was then treated similarly as regards electrodes. P.D. 750 volts 15 seconds application. Horse fell forward the instant the current was applied and gave no sign of life or movement on breaking circuit. Weight estimated at 900 lbs.



$$v^2 = \frac{2v\sqrt{a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma} + \frac{\sqrt{a^2(\beta+\gamma)}}{\left[a^2(\beta+\gamma) - b^2\beta - c^2\gamma\right]^2} = \frac{-\sqrt{2a^2(\beta+\gamma)\left\{a^2(\beta+\gamma) - b^2\beta - c^2\gamma\right\}} + \sqrt{2a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}$$

$$v = \frac{\sqrt{a^2(\beta+\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma} = \frac{\pm\sqrt{\sqrt{2}\,a^2(\beta+\gamma)(b^2\beta + c^2\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}$$

$$v = \sqrt{a}\left\{\frac{a(\beta+\gamma) \pm \sqrt{(\beta+\gamma)(b^2\beta + c^2\gamma)}}{a^2(\beta+\gamma) - b^2\beta - c^2\gamma}\right\}$$

This value of v will involve minimum weight of copper.

Particular cases.

When (1) $b = c$ $\quad b = \infty\gamma\beta$ $\quad v = \sqrt{\frac{a}{a+c}}$

(2) $\beta = \gamma$ $\quad v = \frac{\sqrt{a}\left\{2a + \sqrt{2(b^2+c^2)}\right\}}{2a^2(\beta+\gamma) - b^2 - c^2}$

(3) $a = b = c$ $\quad v = \frac{\sqrt{2}}{2}$

On the winding of a #4 standard Edison armature to give 50 volts mean alternating p.d. when driven in the field of a #4 machine at 300 revolutions per min.

The number of wires all round the O.S. #4 armature is 200. and the number of revolutions 1600 at 125 volts t.p.d.; The same machine as an alternator would give 79.55 volts t.p.d. and at 300 revolutions 14.9 volts at 5 ~. In order to increase to 50 the wires must be 670 = 335 turns.

The circumference available for winding on the armature after deducting for insulation tubes is 17.5" and if 1/2" turns be taken to each layer the diam: of covered wire = 0.031". With 0.015" for cotton leaves 0.076" #15 B.W.G. The depth of winding will be 0.364". This with 6 layers of paper @ 0.007" and two of rubber tape @ 0.010" gives 0.426" or finished diam: 7.142"

The winding will therefore be:—

One #15 BWG 0.072" four turns round (two deep + two wide) in each division, and 96 divisions on the armature = 384 turns in all (two double layers) = 768 wires round the armature.

At normal excitation the alternator will then give 57 volts at 300 revolutions or 304 volts at 1600 revs. per min the frequency being 5 ~ and 26.7 ~ respectively.

On the determination of the least weight of copper in a bifurcating feeder consistent with a given fall of potential from the source to each terminal at a given load.

Let a be the length of a given feeder in cms.
b and c . . . . of its bifurcations . .
σ_a σ_b and σ_c be the conductance of these respectively.
β & γ be the given load currents in b and c (amperes)
V the fall of potential in the whole feeder
v . . . . . a the single part.
K a constant such that w = wt of copper per cm in = $K\sigma$.

Then $V - v = \frac{b\beta}{\sigma_b} = \frac{c\gamma}{\sigma_c}$.

$$b = \frac{a(\beta+\gamma)}{\sigma_a}$$

also
$$w_a = K\sigma_a \qquad W_a = Ka\sigma_a$$
$$w_b = K\sigma_b \qquad W_b = Kb\sigma_b$$
$$w_c = K\sigma_c \qquad W_c = Kc\sigma_c$$

$$\therefore W = W_a + W_b + W_c$$
$$= K\left\{a^2\frac{(\beta+\gamma)}{v} + \frac{b^2\beta + c^2\gamma}{V-v}\right\}$$
$$\frac{dW}{dv} = \frac{-a^2(\beta+\gamma)}{v^2} + \frac{b^2\beta + c^2\gamma}{(V-v)^2}$$

For max: or min:

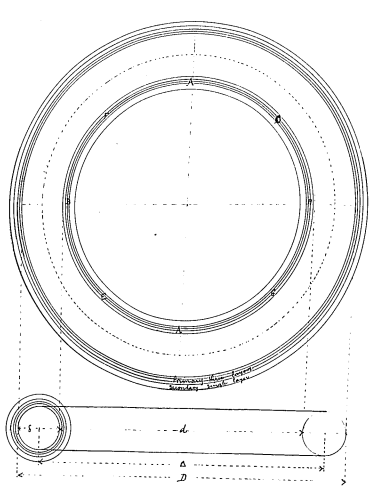
$$\frac{dW}{dv} = 0 \quad \therefore \quad a^2(\beta+\gamma)(V-v)^2 = v^2(b^2\beta + c^2\gamma)$$

$$v^2\left\{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)\right\} - 2vVa^2(\beta+\gamma) = -V^2a^2(\beta+\gamma)$$

$$v^2 - \frac{2vVa^2(\beta+\gamma)}{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)} = \frac{-V^2a^2(\beta+\gamma)}{a^2(\beta+\gamma) - (b^2\beta + c^2\gamma)}$$

Meteorological record.

Date.	Time.	Barometer Readings Inches	Barometer Readings Corrected.	Barometer Readings Temp.	Barometer Readings Corrected. Fahr.	Thermometer. Max.	Thermometer. Min.	Thermometer. Dry.	Thermometer. Wet.	Rainfall 24 hours.	Wind.	Remarks.
1890												
March 1st	Noon	29.674	75.39	75°	29.545	41.0°	38°	38°	—	.27	W.	Cloudy. Rain.
2	"	29.737	75.57	56°	29.672	40°	25°	27°	—		N.W.	Fair.
3		29.882	75.90	65°	29.793	31°	16°	25°	—	.06	W.	Snow.
4		29.894	76.08	71°	29.777	33°	17°	33°	—	—	S.E.	Fair.
5		29.934	76.05	73	29.811	30°	30	34°	—	—	W.	Fair.
6		29.800	75.70	64°	29.704	39°	21°	29°	—	snow	W.	Heavy snow.
7		30.070	76.43	60°	30.006	29°	6°	20°	—	—	W.	Fair.
8		30.100	76.46	66°	29.938	27°	13°	25°	—	—	N.W.	Fair.
9												
10		30.292	76.95	73°	30.169	45°	18°	43°	—	—	S.E.	Overcast
11		30.068	76.37	75°	29.939	44°	30°	40°	—	.32	E	Rainy.
12		29.968	76.12	81	29.821	64°	43°	68°	—	—	S.W.	Fair.
13		29.920	76.00	73°	29.777	67°	45°	64°	—	—	S.W.	Fair.
14		29.882	75.91	77°	29.747	67°	40°	47°	—	.61	W	Rainy.
15		29.652	75.32	74°	29.526	42°	31°	31°	—	.42	W.	Rain storm.
16		29.714	75.73	68°	29.506	41°	25°	32°	—	—		Fair
17		29.470	74.86	73°	29.347	41°	22°	37°	—	—	N.E	Fair
18	Noon	29.511	74.66	75°	29.382	47°	32°	46°	—	—	S.E	Fair
19	"	29.301	74.43	66°	29.173	52°	30°	37°	—	—	W	Heavy snow
20	"	29.997	75.04	77°	28.866	41	22	40°	—	—	S.W	.18 melted snow
21	"	29.385	74.66	76	29.253	47.	37.	48	—	—	S	Overcast.
22	"	29.495	74.94	75°	29.374	50	44	44	—	1.00	S.W.	Rain.
23	"	29.103	75.46	51°	29.446	46	38	40	—	.59	—	Rain
24	"	30.263	76.87	70°	30.149	41	25	35	—	—	S.W.	Fair
25	"	30.213	76.56	74°	30.087	42	31	41	—	—	S.E	Overcast
26	"	29.503	74.94	77	29.366	58	41	53	—	.18	W.	Fair.
27	"	29.763	75.60	76°	29.631	54°	37°	45°	—	—	S	Fair Overcast.
28		29.233	74.26	70	29.119	49°	33	38°	—	.9	S.W.	Rainy
29		29.511	74.99	68°	29.403	41	31	37	—	.04	W	Overcast
30		29.723	75.50	71°	29.604	43	30	41	—	—	W	Snow Overcast.
31		30.123	76.52	73	30.000	49	29	43	—	.05	E	Fair Overcast.
April 1		30.111	76.57	69°	30.000	51°	31°	40	—	—	N.W.	Fair.
2		30.281	76.94	74°	30.186	52.0	27°	41°	—	—	W.	Fair Overcast.
3		30.063	76.36	77°	29.922	62°	32°	52°	—	—	S.E	Fair
4		29.513	75.06	76°	29.481	63°	37°	52°	—	.35	S.E	Rainy
5		29.823	75.76	77°	29.688	59	40	46	—	.31	W	Fair Windy.
6												
7		29.499	74.93	79°	29.358	61°	31°	56°	—	.03	S.W.	Hazy, Overcast, Fair
8		29.777	75.64	81°	29.630	60°	36°	50°	—	.21	S.E	Overcast Rainy.
9		29.373	74.62	75°	29.248	56°	41°	48°	—	.57	S.W.	Rainy.
10		29.453	74.82	81°	29.305	58°	44°	51°	—	.13	S.W.	Fair.
11		29.827	75.77	77	29.771	56	32	43	—	—	W.	Fair.
12		30.043	76.32	80	29.898	66°	40°	57°	—	—	E	Fair
13		29.707	76.47	70	29.593	76	40	76	—	—		Fair
14		29.667	75.30	69	29.556	75	50	68	—	.035	S.W.	Fair
15		30.013	76.24	75°	29.878	70	43	62	—	—	W	Fair
16		30.153	76.60	80	30.009	68	36	61	—	—	S.W.	Fair.
17		29.817	75.76	66	29.785	67	42	59	—	—	S.W.	Fair Overcast
18		29.623	75.25	78°	29.486	63	43	52	—	—	W	Fair
19		29.945	76.07	69	29.830	69	29	45	—	—	N.W.	Fair
20		30.085	76.43	60°	30.001	63	35	54	—	—	S.W.	Fair
21		30.083	76.42	64°	29.981	67	42	59	—	—	W.	Fair
22		30.133	76.54	65°	30.034	16	43	63	—	—	W.	Fair Overcast
23		29.953	76.09	60°	29.869	68	38	66	—	—	E	Fair Overcast
24		29.813	75.81	66°	29.711	76°	56°	74°	—	—	S.E	Overcast
25		29.868	76.10	72°	29.749	76	44	64	—	.26	W	Rainy.
26		30.133	76.52	73°	30.010	49	33	45	—	.01	N.	Foggy
27		29.583	75.22	59°	29.502	48	48	40	—	.24		Rainy
28		29.859	75.93	62°	29.769	61	44	56	—	.01	N.W	Overcast Fair
29		29.803	75.71	64°	29.787	69	40	59	—	—	S.E	Overcast Fair
30		29.671	75.40	76°	29.539	61	45	57	—	—	S.E	Overcast Fair
May 1		29.525	74.00	68	29.444	82	53	75	—	.15	N	Overcast
2		29.943	76.07	68	29.857	18	39	53	—			Overcast



d at A.A. 19.80 at B.B 19.1 Mean 19.95

D - B.B 25.1 - A.A. 25.1 " 25.1

Δ " 22.03

δ - C 3.1 at E 3.1 at F 3.2 at G. 3.2 - 3.15

δ_1 3.65 δ_2 3.9 δ_3 4.3 δ_4 5.0

364 turns of s.c. covered copper wire 0.0145" (0.126) covered

6 0.056" (0.142) layer on first layer above oil paper.

358 turns of same wire on second layer above oil paper

352 - - - - third - - -

1074 - in all on primary circuit

280 - of same wire on one layer in secondary circ.

The induction through the external coil of n turns from a primary of 3 layers each having p_1 p_2 + p_3 ($p_1+p_2+p_3$) m turns is

$$4\pi n m \left[\frac{\pi \delta_1^2 + \pi \delta_2^2 (\mu-1) + \pi \delta_3^2 + \pi \delta_4^2 (\mu-1) + \pi \delta_5^2 + \pi \delta_6^2 (\mu-1)}{8} \right] + \left\{ \pi (\delta_1^2 - \delta_2^2) + (\delta_3^2 - \delta_4^2) + (\delta_5^2 - \delta_6^2) \right\} + \pi \delta_1^2 \mu$$

$$\pi \delta^2 m m \left[\delta_1^2 - \delta_2^2 + \delta_3^2 - 3\delta_4^2 \right]$$

$\therefore$

$$\frac{4N}{D} = \frac{4296}{22.03} = 195.0$$

Permeability of Iron Sample from Schenectady.

An anchor ring of iron containing 7 parts by weight of aluminium to 107 of ordinary cast iron or 6.54 % was cast at Schenectady in company with a series of other samples. The weight of the ring in air was 139 oz (3940 grs) and in water 118.5 oz (3360 grs) corresponding to a sp. gr. of 6.79. The dimensions of the ring are shown on the opposite page. The volume of the ring should be $\pi D \Delta \delta = 9.87 \times 2.203 \times 3.1 = 67.14$ cc. Three layers of primary wire were connected in series and brought to a reversing switch which was brought to the 118 volt dynamo thro galvanometers and resistances. The discharge through the ballistic galvanometer in the secondary circuit represents 560 times d single induction.

No. of Expt.	Condenser	Coll. & Imp.	q.	Throw.	Mean throw accepted	Value of 1 div		
	1 μ	1 1 2.442	1.4275 × 10⁻⁶	172 176.5 176.5 175.5 176.5 176 175.5 175 179 179 175.5	179	7.972 × 10⁻¹⁰ abs. qu.		
		1 2						
		1 3						

N.B. Cross

No. of Series	Clock Gauge	C.	(B-B)	No. of Obs.	Mean Throw	Aver. in cat.	Total cor. of cat.	Q/250	Q/Mass	Q/πD²Δδ	Q/π²N(ad)²	Σ(Δd²)/Nd²	μ	B
1	5.25'	0.0426 0.0426	16.64 16.44	4	127	–	5250	3.546 × 10⁻⁶	2.018 × 10⁻⁶	2.48 × 10⁻⁶ 2.45 × 10⁻⁶	27.7	0.58	26.49	25.55
2	6.15'	0.0836		5	146.2			6.578	3.453		12.56		26.92	43.37
3	9.0'	0.1194	23.29	90	64.2			9.102	4.80		18.15		25.87	60.26
4	13.45'	0.1765	35.98	5	96			1.523 × 10⁻⁷	7.996		28.04		27.94	100.5
5	17.30	0.2379	46.38	7	139			1.939 × 10⁻⁷	1.039 × 10⁻⁶		36.114		28.17	130.7
6	0.065	23.5'	0.3213 0.3230	63.6	5	198.6	–	2.827	1.484		49.55		29.37	186.8
7	0.215		1.092	2.13	3	245	25.000	3.256	1.710		166.4		62.62	1330
8	0.240		1.219	237.7	9	264	25.000	3.739	1.963		195.36		60.79	1446.5
9	0.245		1.246	242.6	4	143.1	50.000	2.017	1.025		189.1		58.87	1428
10	0.271		1.376	268.4	6	176.5	50.000	2.513	1.318		229.2		65.75	1765
11	0.312		1.584	308.9	5	222	50.000	3.161	1.746		285.6		71.93	2224
12	0.359		1.823	355.5	4	271.6	50.000	3.867	2.136		277.1		76.50	2720
13	0.359		1.823	355.5	4	136.9	100.000	1.949	2.051		277.1		73.44	2612
14	0.443		2.183	425.8	5	173	100.000	2.463	2.592		331.8		77.52	3301
15	0.525		2.666	521.9	4	207	100.000	2.947	3.102		405.2		75.98	3966
16	0.513		4.128	805.1	4	278	100.000	3.958	4.166		627.5		63.39	4388
17	1.35		6.852	1337	4	320.5	100.000	4.553	4.793		1012		46.09	4985
18	1.780		8.934	1753	3	195	200.000	2.776	3.592		1361		44.57	4788

$$\pi^2 m n d^2 = 9.8696 \times 280 \times 1074 \times 9.924 = 2.946 \times 10^7$$

where $4.0 \times 10^7 \times 2.8 \times 10^2 \times 1.1 \times 10^3 \times 1.42 \times 10^{-2}$

$$\pi^2 N d^2 = 9.8696 \times 1074 \times 9.924 = 1.052 \times 10^5$$

$$\frac{\pi^2 N}{Q} d^2 = \frac{1.052 \times 10^5}{6.92 \times 10^7} = 1.520 \times 10^3$$

$364 \times 3.65^2 = 4849$

$358 \times 3.9^2 = 5445$

$352 \times 4.3^2 = 6508$

$1074 \times 3.15^2 = 16,802$ } 1.576

area of ring = 7.792 sq. cm.

Calculation of the correction for winding spaces to be applied to a continuously wound Faraday ring before the true value of the permeability can be deduced.

Let d be the diameter of the cross circular section of iron (cms)
" d_1 " " " " " 1st layer of primary (mean) cms.
" d_2 " " " " " 2nd " " "
" d_r " " " " " rth " " "
" n_1 " " number of convolutions of 1st layer
" n_2 " " " " " 2nd "
" n_r " " " " " rth.
" m " " total " " " in secondary layer or layers assumed to be symmetrically disposed.
" $N = (n_1 + n_2 + \quad + n_r)$
" μ be the true mean permeability
" γ_0 " " strength of the magnetizing current (abs. mag) mean ring circumference

Then the induction φ through the secondary is expressed by the equation

$$\varphi = 4\pi m \gamma_0 \left\{ \frac{n_1\pi}{\sigma_1}(d_1^2 - d^2) + \frac{n_2\pi}{\sigma_2}(d_2^2 - d^2) + \frac{n_r\pi}{\sigma_r}(d_r^2 - d^2) + \quad + \frac{4N\pi^2}{\sigma_r}\mu d^2 \right\}$$

$$= 4\pi^2 m \gamma_0 \left\{ \frac{n_1}{\sigma_1}(d_1^2 - d^2) + \frac{n_2}{\sigma_2}(d_2^2 - d^2) + \frac{n_3}{\sigma_3}(d_3^2 - d^2) + \quad + \frac{N}{\sigma}\mu d^2 \right\}$$

$$\pi^2 m \gamma_0 \frac{N}{\sigma}\mu d^2 = \varphi - \pi^2 m \gamma_0 \left\{ \sum \frac{n_r}{\sigma}(d_r^2 - d^2) \right\}$$

$$\therefore \mu = \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} - \frac{\left\{ \sum n_r (d_r^2 - d^2) \right\}}{N d^2}$$

$$= \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} - \frac{\sum n_r d_r^2 - N d^2}{N d^2}$$

$$= \frac{\varphi}{\pi^2 m \gamma_0 \frac{N}{\sigma} d^2} + \left(1 - \frac{\sum n_r d_r^2}{N d^2}\right)$$

When the winding space is negligibly small $\sum n_r d_r^2 = N d^2$ and the correction vanishes.

For a hollow ring solenoid enclosing a vacuum the induction would be $4\pi m \frac{N}{\sigma} d^2 \frac{\pi}{4} \gamma_0 = \pi^2 m \frac{N}{\sigma} \gamma_0 d^2$ and μ reduces to 1 so the above equation checking its accuracy

H is always $= \frac{4\pi N \gamma_0}{\pi D} = \frac{4 \cdot N \gamma_0}{D}$ where D is the mean diameter of the ring along the lines of force. $= 4 \frac{N}{\sigma} \gamma_0$

Error of Barometer Scale in Galvanometer Room (Office observed 16th Mar. 90 by cathetometer

Altitude of 27" mark.	88·052	upper telescope	88·052	
" " lower side of 100" mark on scale of thermometer	62·011		62·011	
	26·041		26·041	26·044
Altitude of 100" mark as above	57·396	lower "	57·396	
" " base point	14·803		14·803	
	42·493		42·493	42·493
" 27" mark above base point	68·535			68·537

At a distance of 90 cms 1 div: of level bubble represents 0·01 cm Mean 68·536.

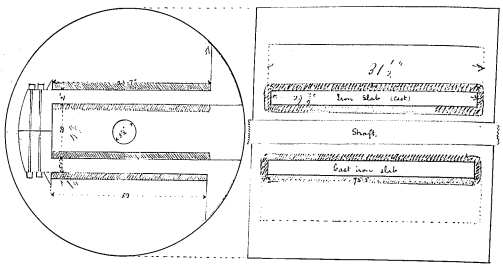
27"·000 indicated	68·580 cms indicated	
26·983 observed	68·536 " observed	
·017" over indication	0·044 " over indicated	

So that 0·017" or 0·044 cms have to be subtracted from reading.

Scale 1/10

Section of interior of drum at right angles to axis.

Section of interior of drum through axis.



240 lbs of ⅜ in B.W.G. on each slab or 480 lbs in all.

On the winding of an ore-milling magnet to be operated within a revolving brass drum.

The free surface of this magnet will be 85 × 60 × 2 = 10200 sq. cms. and allowing 20 sq. cms. per Watt gives 510 Watts available. = 100 volts @ 5·1 amperes. The res: must therefore be $\frac{100}{5.1}$ = 19·61 ω (that) say 19·6 ω or

The diameter of the wire intended to be used is 0·109" (12 B.W.G.) ground to 0·128" and 23/128 = 180 turns in one layer and each turn will be about 5·5' so that 1 layer will have 990 feet = 1·13 ω.

15·6 ω @ 163·39 lbs per ω = 600 lbs = 3140 lbs ω 7·84 ω on each slab = 7 layers on each slab.

The total number of feet will be 7 × 180 × 5·5 = 6930 on each half (1260 turns) and 2520 turns or 13860' feet on the magnet.

2520 × 5·1 = 12850 ampere-turns.

Measurement made to secure the accuracy of two standard resistances of copper wire, one for Messrs Bergmann & Co., and one for ourselves, each to be 46·46 ω of copper @ 70°F (21·1°C) and to be of # 29 B.W.G.

Preliminary measurement. 300 cms. of this wire 0·0124" diam: counts to 0·015" = 0·677 ω @ about 20°C. = 2.257×10^{-3} ω per cm.

The wire for 50 ω as 1st approximation will have to be wound on an arbor 17·35 cms: in diam = 54·5 cms: in circumference.

$50/2.257 \times 10^{-3} = 22.15 \times 10^{3} = 2.215 \times 10^{4}$ cms: of wire

$2.215 \times 10^{4}/5.45 \times 10^{1} = 406.4$

Measurements made of the energy required to be delivered by a battery for electro cauterizing purposes.

As contained from Dr. Edward Yatman of Yonkers N.Y. that the diam: of platinum wire used in electro cautery is generally 0·0253", and that "while 2" is frequently sufficient "the length used does not probably exceed 4" in any of the burners ordinarily employed". Very rarely 6 or 8" of # 18 wire 0·0140" have been used.

Experimented with Pt. wire 0·016".

15·25 cms: of this wire was brought to bright redness by a current of $\frac{1.62}{0.19}$ = 7·02 amperes when the p.d. on the wire was 4·5 volts.

4" = 10·2 cms. + $\frac{10.2 \times 4.5}{15.25}$ = 3·0 volts.

Next tried 4 wires each 0·012" diam. the strand being 0·025" in diam. This was brought to vivid redness by $\frac{2.60}{.197}$ = 13·2 amps. and the p.d. on 15·25 cms. was 3·5 volts. on 10·2 cm it would be 2·33 volts.

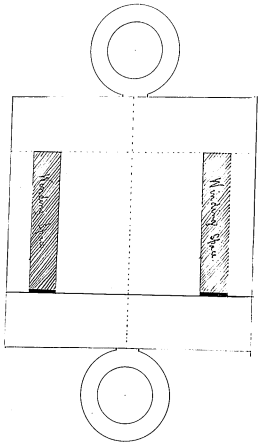
For the 0·016" wire, assuming each K.H.O. cell to have 0·7 volt and 0·03 ω int: res:

$3.0 = 0.7n - 7 \times 0.03n \quad \therefore n(0.7 - 0.21) = 3.0 \quad n = 6$

For the 0·025" wire assuming the same values

$2.33 = 0.7n - 13.2 \times 0.03n \quad \therefore n(0.7 - 0.396) = 3 \quad n = 10$

allowing negligible resistance in the leads.



Cross section in diametrical plane.
Full size.
Annealed wrought iron.

On the Dimensions of an Electromagnet capable of sustaining 200 lbs weight.

The formula for lifting power is

$$Wg = 2\pi I^2 + HI$$

Where W = mass lifted per sq. cm. cross section
g = acceleration of gravity
I = moment per c.c.
H = field.

$$I = \kappa H$$

and $\mu = 1 + 4\pi\kappa$

$$\therefore \quad I = \frac{H(\mu - 1)}{4\pi}$$

and

$$Wg = \frac{H^2(\mu - 1)^2}{8\pi} \qquad \ldots\ldots (1)$$

Where μ is a large number this reduces to

$$Wg = \frac{H^2\mu^2}{8\pi}$$

$$= \frac{B^2}{8\pi}$$

By employing wrought iron with $H = 40$ $\mu = 1000$ say

$$Wg = \frac{100{,}000{,}000}{25}$$

$$= 4{,}000{,}000$$

W = 4000 gms. per sq. cm.

200 lbs = 90600 = 22.75 sq. cm. cross section.

With a circular core = 5.4 cms in diam. = 2.2".

For H to be 50 as factor of efficiency of 4
there must be 40 ampere-turns per linear cm.

With a clearance of 1 cm. on a side we have

$$0.7854(x^2 - 7.4^2) = 22.75$$

$$x^2 = 54.76 + 28.97$$

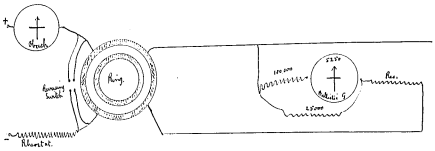
$$= 83.73$$

$$x = 9.15$$

The mass of the magnet thus formed, and represented in section on the opposite page will be:–

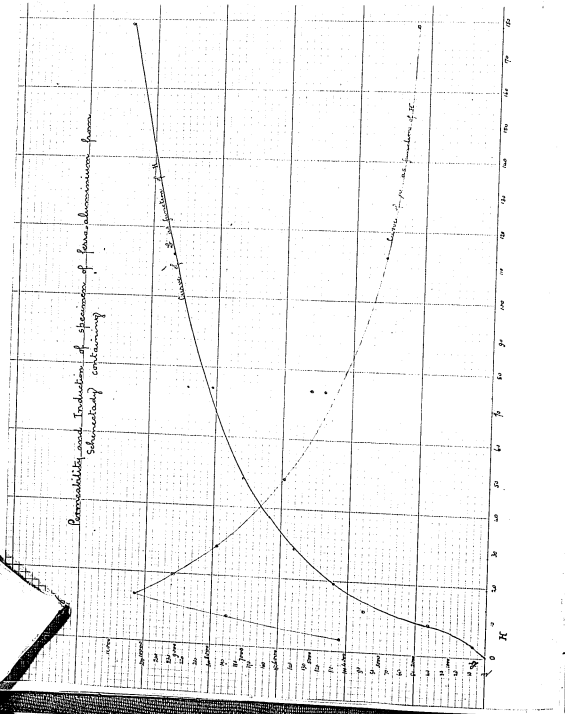
approximately $\dfrac{9.15 \times 0.7854 \times 9.15^2 \times 7.7}{453.6}$ lbs

$= 10.2$ lbs.



$$\phi = \frac{7\,d \times 5.91 \times 10^{-10} \times 5.21 \times 10^{8}}{2 \times 364} = 4.23 \times 10^{-3}\ \text{rd}$$

$$H = \frac{990 \times 1.257 \times C}{2g \cdot 2} = 17.98\ C$$



Permeability of sample of iron from Schemectady. contd from page 14.

The ring whose test on page 14 was found to be in error was again used. The inner layer of 360 turns was used as the demagnetising coil, and the outer (two layers connecting) 990 turns were used as primary. The following observations were then obtained:—

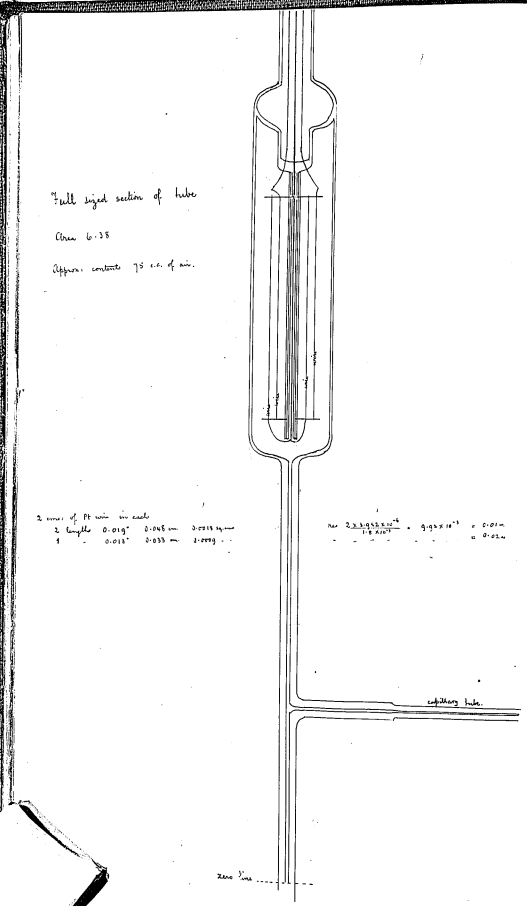
No.	Bell + Leads	a	Throw on Ballistic G.	v	$\frac{0.1453 Zv}{m\sqrt{n-1}}$	Result	Value of 1 div. in q.
1	1.4275 + 1	1.4275×10^{-7}	240	−1.6			
2			236	+2.4	0.0332 × 10.9		
3			239	−0.6	0.363	238.4 ± 0.4	$\frac{1.4275 \times 10^{-7}}{2.4415 \times 10^{4}}$
4			236.5	+1.9			
5			238	+0.4			
6			241	−2.6		Point of reversal 40 secs.	
7			239	−0.6			
8			238	+0.4			
9			238	+0.4			= 5.91 × 10⁻¹⁰
			7149	+ 0			
			238.4	± 10.9			

No. of Obs.	Time	Standard Galvo.	Steady	Current amp.	H 4.23 T	No. of Obs.	Mean Throw	Res. of Galvo.	Res. in manganin	Total res. in circuit	q	B	μ	H
1	9.20	41°50′		2.199	8.26×10^{-6}	6	314.3	20 200	–	20,200	2932	376 9.2%	105	3.58
2	.40	31°45′	0.096	0.467 / 0.457		4	150.4		–	–	12,960	1650 33%	188.4	8.57
3	.55		0.150	0.762		7	321.7				27,500	35303.2%	257.5	13.71
4	10.03		0.210	1.066	1.92×10^{-5}	5	179.4	–	25000	45200	34,200	4460 0.37%	129.5	19.77
5	10.19		0.310	1.574		7	227.8	–	–	–	43560	5590 0.6%	197.0	28.31
6	10.25		0.527	2.676		5	290.6	–	–	–	55570	7130 0.7%	148.2	48.13
7	.47		0.81	4.112		1	360	–	–	–	68,820	8830 0.9%	119.4	73.96
8	.45		0.81	4.112	2.97×10^{-5}	2	213	–	50000	70200	63,260	5120 0.7%	109.8	73.96
9	10.53		1.295	6.268		3	245	–	–	–	72,770	9140	82.9	112.7
10	.57		1.955	9.924		4	280	–	–	–	93,180	10780	59.9	178.5

$D = 0.1025 + 0.000059\,H$

Bell + leads	a	Throw on Ballistic G.	v	μv	$\frac{0.1453 Zv}{m\sqrt{n-1}}$	Result
1.4275 + 1	1.4275×10^{-7}	242.5 (1)	2.05	4.1	0.1 × 13.35	244.55 ± 0.4
		249 (1)	4.65	4.65	= 1.335 error of single obs.	
		243 (1)	1.55	2.10	+ $\frac{1.335}{\sqrt{11}}$ = 0.4	
		245 (1)	0.45	1.35		
		245 (1)	0.45	1.35		244.55
		$\frac{50}{11}$ = 4.55		13.35		238.4
		244.55				482.95
						241.475 Mean of both results.

Multiplying power of Shunt 5.21



Experiments upon the temperature coefficient of resistance of copper.

(9)

Kennelly and Fessenden.

Three attempts had been previously made to determine the rate and change rate of this coefficient by means of a coil of copper wire in a glass chamber filled with air employing the principles of the air thermometer, but in each case the result proved abortive from mechanical deficiencies. Apparatus #1 was a larger glass tube heated by an oil bath itself heated by bunsen burner. This bulb leaked and the general method was unsatisfactory. #2 was a similar tube drawn to scale on page 142 Book II. This bulb burst for want of strength when subjected to the stress of heat pressure. #3 was a smaller tube on an improved plan but when completed the coil of wire within was found to be broken. The following however is a description of #4, which was more successful.

A glass tube about 0.25 in diam. ext. and 18 long formed a shaft in the axis of a larger tube blown into a bulb. This outside bulb was of the dimensions shown on the opposite page. At nearly equal intervals along the central tube shaft and at planes at right angles thereto were fixed disks of mica each 1.9 in diameter. These were kept in place by washers of glass tubing fitting closely upon the inner shaft. All these disks were bored with 15 holes in two concentric rings, and through these holes one fine wire was longitudinally threaded ~~backwards~~ up and down in direct succession, the inner circle being completed before the outer circle was ~~complete~~ completed. About 120 cms. of the wire was thus threaded in each circle, the diam. of the inside circle being about 1.0 and that of the outside 1.6. The resistance of each circle was about 10 ω at normal temperature. Wires to the ends and junction of these circles were led through platinum seals outside the tube, in the manner of incandescent lamp connections.

The wire was of copper 0.0051 in diam (0.002"). It was originally silk covered, but the covering was removed by immersion in strong KHO solution.

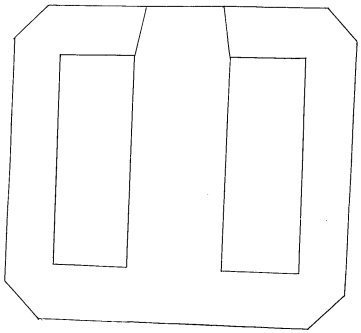
The bulb terminated below in a narrow tube of glass 0.4 in diam. ext. and 0.6 ext. and about 15.2 long to the zero line. At right angles to this tube there projects another at right angles as shown. By observation on a separate tube it has been determined that the approximate capacity of this length of tube in both directions is 0.2 c.c.

Surrounding the bulb is a frame wound with 16 ω of platinoid wire, and outside this conical frame is a shell of asbestos. The whole bulb & frame are then contained in a percolator through whose orifice the lower end tube passes water tight by a rubber stopper. The percolator was then filled with boiled linseed oil, and a disk of asbestos laid on above as a cover. About 3 amperes was passed through the platinoid wire and served to raise the temperature of the oil bath.

A bottle of mercury was suspended from the ceiling by a cord over two pulleys and a counterpoise sand-bottle. The mercury bottle communicated by rubber tubing with both the lower glass tube of the bulb and a long vertical index tube. At starting, the temperature and pressure of the air in the bulb was determined and the capillary offset tube then sealed by blowpipe while the mercury stood at the fiducial mark. The heating current was then passed through the platinoid coil as soon as the resistances of the enclosed coil had been determined. The heated enclosed air as it drove the mercury downwards was forced back to zero by raising the mercury bottle and reading off the increase of level by cathetometer on and off the index tube. The bulb had been repeatedly exhausted before commencing and refilled with dried air.

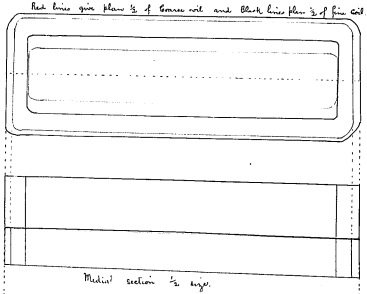
Experiments on the Temp: Coeff: of copper continued.

No. of Obs.	Calorimeter Reading	Calorimeter Rise:	Resistance with heat distributed a	coil b	a & b	Time 16. II. 90	Temp: of Hg:						
1	11.326	zero	9.922	9.839	20.267	20.1265							



Plan of one plate in transformer
actual size.

Red lines give plan ½ of Primary coil and Black lines plan ½ of fine coil



Medial section ½ size.

Tests of a Westinghouse Converter.

Weight of converter without shell

Primary coil	1520
Secondary	1560
Iron plates	9580
Bolts & frame	1170
	13830

Each plate has a thickness of 0·007" to 0·008" and the paper 0·003" to 0·004".
The coils have the dimensions shown

Resistance of primary coil 22·28 ω.
" " secondary " 0·05 ω.

In primary coil 16 layers of 45 turns each = 720 turns.
" secondary " 5 " 7 " " = 35 "

Diam: of primary wire 0·025"
" " secondary " 0·127"

As it was difficult to ascertain the permeability of the magnetic circuit accurately owing to the want of symmetry in the arrangement a fixed current was passed through the primary coil, and the effect of its reversal noted on the ballistic galvanometer placed in the secondary circuit. The plates were then all removed and iron wire 0·0265" wound on in to plates by hand through and through. The weight of wire added was 21100 gms: or 0·22 of the weight of plates. The experiment was then repeated with following results.

With plate magnetic ct.							With wire magnetic ct:							
Deflection of galvo.	Current	Rev. of Ballistic ct.	Turns	value of 1 div. sec.	φ		Deflection of galvo.	Current	Rev. of Ballistic ct.	Turns	value of 1 div	φ	φ approx.	
27·30	0·393	205,250	197	7·97200	4·605×10⁵		27·30	0·393	205,250	62	7·85500	2·31305 × 62 = 1·434×10⁵		

If the weight of wire were increased to that of the plates we might expect a corresponding increase in induction i.e. to 6·518 × 10⁵ an increase of 41·5% over the induction with plates.

22·28 × 0·[illegible] = 2·551 Volts.
[illegible] × [illegible] = [illegible] × [illegible] = [illegible]
22·28 × [illegible] × [illegible] = [illegible]

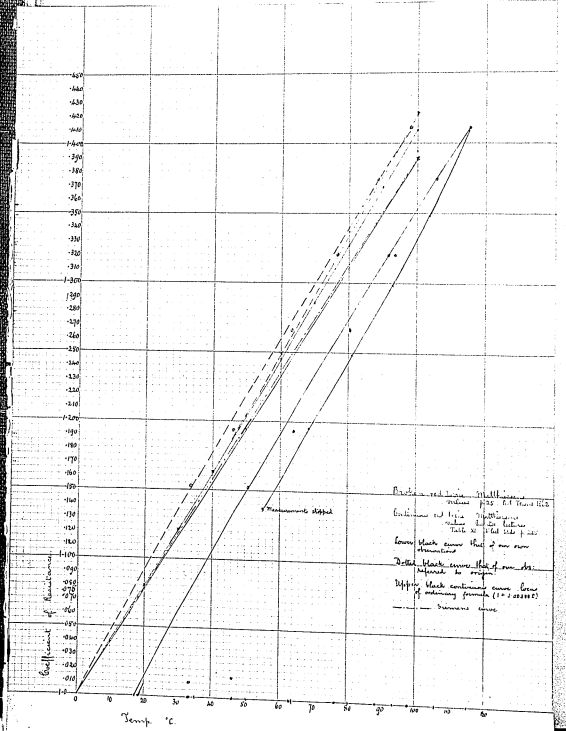
The inductance is 600,000 lines (φ) for one ampère × 730 = 438,000,000 = 0·438 quadrant. for the primary. The inductance mutually excited on the secondary will be 600,000 × 35 = 21,000,000 = 0·021 quadrant and the inductance of the secondary on itself will be presumably 1,018,500 = 0·001 quadrant.

Res. of leads in the apparatus itself = 2 cms. of platinum 0.010 in each wire
+ 0.014 0 0.021 − 0.014

Res. of leads proper a + b 0.328 + 0.037 = 0.365
b + c 0.326 + 0.037 = 0.363
a + c 0.343 + 0.025 = 0.371

Observed height of barometer when sealing off bulb 74.82
Index error +0.46
74.776
Correction for temp. −.267 (67.8)
74.509

Temp. of oil bath by Std. Thermometer 17.2° C.

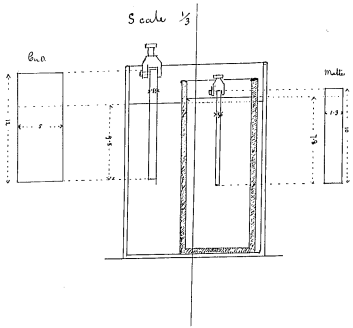


Time	Temp. of Bath	Approx. temp. of bath	Temp. of Bridge	Observed res. with leads	Corrected for leads 0.365	Observed res. for a	Corrected for leads 0.363	Observed res. for b	Corrected for leads 0.371	Galvanometer reading	Height of barometer	Temp. of Bath by calibrated th.	Observed temp. of Bath
20.0	15.4°C.	17.2°C.	20.5°C.	10.250	9.885	10.265	9.902	20.170	19.799	11.925	0	1.00279	15.4
.12				10.990	10.625	11.150	10.787		19.797	16.638	4.712	1.00283	15.6
.30				1		11.620	11.257	23.160	22.809	20.594	8.868	1.00287	15.8
.40				12.280	11.915	12.280	11.917	23.980	23.609	23.946	12.020	1.00290	16.0
.58			21.5°C.	12.960	12.595	12.970	12.607	25.440	25.069	28.270	16.344	1.00294	16.2
21.13				13.49	13.125	13.485	13.122	26.500	26.129	31.650	19.734	1.00297	16.4
.25		100°–105°		14.03	13.665	14.00	13.637	27.550	27.179	34.806	22.880	1.00301	16.6
.38	16.8°	102°–103°		14.36	13.995	14.30	13.937	28.300	27.929	37.158	25.232	1.00305	16.8
.55								27.050	26.679	36.260	22.332	1.00305	16.9
.00								26.070	25.699	31.435	19.510	1.00303	16.7
.06								25.070	24.699	28.320	16.394	1.00303	16.7
.16								24.02	23.649	25.190	12.264	1.00301	16.6
.29	16.6°		22.2°	11.620	11.255	11.600	11.237	22.97	22.599	21.790	9.864	1.00301	16.6
									295.828	345.984	192.946 152.938 345.884		

	Place of Bridge wire cell 6.05	Total No. of cells (+70/300)	Coeff.	Abs. temp. of wire at beginning	Abs. temp. of wire at time	Temp. by wire thermo. °C.	Resis. °C.	Resis. of res. Ω	Coeff. of res.	Coeff. per °C. wire	res. of 0°C	Curve of calibrate	Difference (Calc.) which
	–	70.510		17.2°C.							19.799	19.787	0.012
2	4.700	79.210	1.0631	= 290.2	308.5	35.5	18.3						
3	8.640	83.156	1.1160		323.7	50.7	33.5	3.010	1.1521	0.004537	22.809		
4	11.990	86.500	1.1609		336.9	63.9	46.7	3.810	1.1928	0.004129	23.609	23.832	* −0.223
5	16.295	90.805	1.2187		353.6	80.6	63.4	5.270	1.2662	0.004199	25.069	25.202	−0.133
6	19.670	94.180	1.2640		366.8	93.8	76.6	6.320	1.220	0.004178	26.129	26.247	−0.118
7	22.810	97.320	1.3061		379.0	106.0	88.8	7.380	1.373	0.004201	27.179	27.302	−0.123
8	25.160	99.670	1.3377		388.2	115.2	98.0	8.120	1.411	0.004194	27.929	27.932	−0.003
9	22.270	96.780	1.2989		376.9	103.9	86.7	6.880	1.3148	0.004214			
10	19.450	93.960	1.2610		365.9	92.9	75.7	5.900	1.2982	0.003964			
11	16.350	90.860	1.2194		353.9	80.9	63.7	4.900	1.2479	0.003891			
12	13.228	87.738	1.1775		341.7	68.7	51.5	3.850	1.1950	0.003797			
13	9.836	84.346	1.1320		328.5	55.5	38.3	2.800	1.1142	0.003708	22.599	22.492	0.107
								56.260 237.588 293.848					

On breaking the dynamo circuit through the heating coil in the oil bath, a fall in the resistance of the enclosed wire could be detected within two or three seconds and a fall of pressure by calthermometer in some ten seconds, thus proving that no time lag exists in the apparatus.

* The difference 0.012 at the head of this column is due to some slight want of symmetry or separation of the two interior coils. The greater differences later on are no doubt due to changes occurring in the time necessary to secure the three measurements as they are — for rising and + for falling temperatures.



Electrolysis of Copper Matte. 19th Mar. 30.

A glass battery jar contained a porous cell and both were filled with an aqueous solution of $NaCl$ of density 1·16. In the porous cell, a plate of matte was immersed 10 × 1·9 × 0·45 and exposing 38 sq. cms. to the liquid. In the outer jar was suspended a plate of phonographic cell compressed CuO. 12 × 5 × 0·85 exposing 180 sq. cms. The CuO plate weighed 227·6 grammes and the matte plate 57·8. The resistance of the whole cell was at first very high but by keeping the current from the dynamo through two lamps (1·1 amp) for 30 mins. the resistance of the cell at the end of that time was 1·8 ω. The following series of readings were then taken.

No. of Obs.	Lamps in cct.	Shunt reading	Current amperes	Density amp. per sq. matte	Density amp. per sq. foot	P.D. in cell volt	Res. of cell by bridge	P.D. due to res. volts	Counter emf volts	
1	1	0·098	0·49	129	12·18	3·0	1·8 ohm	0·9	2·1	
2	2	0·225	1·125	296	27·88	4·3		2·03	2·27	
3	3	0·340	1·70	448	42·1	5·4		3·06	2·34	
4	4	0·450	2·25	592	55·7	6·4		4·05	2·35	
5	5	0·550	2·75	724	68·1	6·9		4·95	1·95 ?	
6	6	0·650	3·25	856	80·5	7·6		5·85	1·75	
7	7	0·730	3·65	961	90·3	8·2		6·57	1·63	doubtful
8	8	0·840	4·2	1105	104	9·1	~~1·27~~ ?	7·56	1·54	
9	9	0·930	4·65	1224	115	9·5	~~1·32~~	8·37	1·13	
10	10	1·050	5·25	1380	130	10.	~~1·38~~	9·45	0·55 ?	
11	2	0·225	1·125	296	27·8	3·3	1·25 ohm	1·41	1·9	

Very little polarisation is visible in testing the cell but there is a nearly steady initial counter e.m.f. of nearly 2 volts. Testing current put on at 11.20 until 12.10 and from 13.40 to 17.30 when the matte was scraped. The resistance of the cell after scraping was about 1 ω (rather less 0·98), and the current 1·18 amp. the p.d. 2·3 volt. The scraping of the matte reduced the p.d. by 1 volt as it had been 3·3 volt for a long period previously. The counter e.m.f. after scraping would thus be as low as 1·2 volts.

The current was stopped at 20.50 when the p.d. was and the current 1·18 amp.

The weight of the matte plate after scraping and drying was 45·915 gm. The total loss was 11·9 grammes.

The current was 1·1 amp. from 11.30 to 12.10 = 0·67 hr @ 1·1 amp = 0·737
" " " 1·13 " " 13.40 . 18·0 = 4·33 = 0·113 4·90
" " " 1·18 " " 18·0 . 20.50 = 2·83 @ 1·18 3·33
8·97

8·97 amp. hrs. dissolved 45·915 grammes of matte.
1 " " " 5·12 " " " = 0·0113 lbs.
or 88·6 amp. hrs. will be needed for 1 lb. of matte. = 0·00393
342·2
2000 × 88·6 or 177200 . . . . . 1 ton .
646,000
Taking the e.m.f. of disruption at 2 volts (mean), each amp. does 2 foot lbs. of work in one second or 7200 foot lbs in one hour.
4 hr. 1000 1525200
177,200 × 2 = 354,400 watt hours = 12.62 H.P. hours electrical.
2000
@ 90% = 8154 mechanical H.P. hours

for electrolytic-force work alone independent of work against resistance

With H.P. for $50 per annum of 24 × 360 = 8640 hours, the cost of 1 H.P. hr = 50/8640 = 0·579 d so that 1 ton of matte will cost $2.97 for work expended in disruption.
21·81

If it were possible to keep the surface of the matte quite clear of debris, then the p.d. would be reduced in ratio 1·2/3·0 or 40% and the price per ton would become $1·50.

Electrolysis of Matte contd.

The experiment recorded on the last preceding page was repeated under two variations. (1) Using a carbon plate instead of a CuO plate (2) Using a solution of KNO_3 in H_2O instead of NaOH

Two battery jars with porous pots of practically the same dimensions as those shown on the preceding page were made up. No. 1. had a plate of matte 10 x 2 x {0.7 (matte)} immersed to a depth of 9.3 also a plate of CuO. 12.2 x 5 x 0.85 immersed to a depth of 9. The matte exposed superficially about 22 sq. cms. and the CuO about 65. The solution was KNO_3 in water the sp. g. being 1.26 in the outer and 1.20 in the porous cell. at 21.5°C. The weight of the matte plate was 57.61 The resistance of the cell was at first very high but reduced to 1.95 ω after about 20 mins. passage of 1 ampere.

No 2 cell had a matte plate 10 x 2 x {0.7 (matte)} immersed to a depth of 8, and a carbon plate 11.5 x 5.7 x 1.25 immersed to a depth of 10. The matte plate thus exposed about 25 and the carbon plate about 76 sq. cms to the liquid, which was an aqueous solution of NaOH sp. g. 1.156 at 21°C. The weight of the matte plate was 61.92. The resistance of this cell at starting was 0.7 ω. The dynamo current was sent through these cells in series and the clock at 11.22. the matte plates being the anodes. The current commenced at 0.88 amp: at 16.00 the matte plates were scraped. The debris on the KNO_3 plate was hard and stiff, that on the NaOH plate soft and yielding. At 19.55 the plates were scraped again. The observations during the run are shown in the table.

No. of Obs.	Time	Clock	Current	Amp. hrs.	Obs. P.D. (1) volts	Obs. P.D. (2) volts	Clock rec. (1) ω	Clock rec. (2) ω	P.D. from b rec. (1) volts	P.D. from b rec. (2) volts	Counter e.m.f. (1) volts	Counter e.m.f. (2) volts	Matte Equivalent density (1) amp. hr.	Matte Equivalent density (2) amp. hr.	Matte Equivalent density (1) amp. hr.	Matte Equivalent density (2) amp. hr.			
1	11.22	0.175	0.88	-			-	-											
2	.30	0.198	1.00	0.12	7.0	2.0	·	0.7		1.4		0.6							
3	.50	0.20	1.0	0.33	7.0	2.0	2.0	0.7	3.0	1.4	4.0?	0.6							
4	15.00	0.20	1.0	3.16	9.0	3.5	1.5	0.74	1.5	0.7	7.5?	2.8	4.55	4.00	42	37	Stopped to replace		
5	16.00	0.2	1.0	4.16	10.0	3.6													
6	16.40	0.215	1.08	4.91	3.2	2.3	1.5	0.7	1.6	0.7	1.6	1.6					Started		
7	16.30	0.215	1.08	0.96													Stopped for replacement		
8	16.40	0.23	1.16	0.00													Started		
9	19.55	0.212	1.07	3.66	10.5	3.6	4.9	1.3	5.2	1.4	0.2?	2.2					Stopped to change		
10	20.40	0.23	1.16	0.00	2.7	2.5	1.2	0.95	1.39	1.1	1.3	1.1					Started		
11	20.53	0.22	1.11	0.83													Stopped		
				9.44															

After swapping, drying and weighing the matte plates were

No. (1) 34.210 gms. equivalent to a loss of 17.41 g.
(2) 28.275 " " " " 13.665

No. 1. losing 17.41 g. in 9.44 amp: hrs dissolves 1.8443 gms. per amp. hr. &
" 2 " 13.665 " 9.44 " " " 1.4477 " " " "

96 1 lbs 1 lb in 2146 hrs 1 ton of 2000 lbs in 4.92000 kmp. hrs
" 2 " 1 " 313.5 " " " " 627000 " "

The mean counter e.m.f. in the no 1. cell was about 3.0 volts
" " " " " " 2 " " 2.0 "

The energy expended per ton in £1 is 14.76 Kwt. hrs for counter e.m.f.
" " " " " £2 " 15.24 " " " " "

1 Hp. hr. cost @ £50 per annum 0.5780 d
1 Kwt. — " " " " 2.776 = £11.65 for £1 per ton (a 98% cl. £12.72
= £ 9.73 " £2 " " £ 10.51

Electrolysis of Matte contd.

Took 6 battery jars in all important respects similar to the ones already described, with a solution of NaCl in H_2O of density 1.114 at 20°C. The porous cells contained matte plates 10 × 2 × 0.75, immersed for about 8 mm. In the outer jars were plates of carbon in three and plates of copper oxide in three 12 × 5 × 0.85.

The matte plates were weighed before and after the experiment, and two Edison standard meters were included in the circuit.

The experiment lasted more than 24 hour. The density of the solution at the end of that time was 1.165 in the porous cells, and 1.145 in the outer cells. The debris was loose and muddy, easily detached and weighed in all grammes or grammes per cell.

Cells 1, 2, 3 had CuO plates. Cells 4, 5, 6 had Carbon plates

No. of obs.	Time	Clock	Current	Amp. hr. in interval	Amp. hr. to time	P.D. on cells	Res. det.	P.D. due to res.	Corrected EMF of cells.	Remarks.
1	16.25	0.2	1.00	–	–	(1) 6.5 (2) 15.0 (3) 4.1 (4) 1.6 (5) 2.35 (6) 2.6				Started
(2)	17.55	0.198	1.0	1.5	1.5	(1) 3.5 (2) 6.2 (3) 2.0 (4) 1.75 (5) 2.69 (6) 3.65	1.3 1.95 0.9 1.25 1.05 1.0	1.3 1.95 0.9 1.25 1.05 1.0	2.2 2.2 2.1 2.0 2.6 2.6	
3 4	20.37 (8.10) 20.05 (8.10)	0.195 0.205	0.98 1.03	3.66 –	5.16 5.16	(1) 2.5 (2) 3.05 (3) 1.9 (4) 2.35 (5) 2.75 (6) 2.7	1.05 1.20 0.75 1.25 1.15 0.95	1.45 1.20 0.75 1.25 1.15 0.95	1.05 1.85 1.20 1.65 1.60 1.80 } 1.7	Stopped Started
5										Smashed matte plates
6	8.20	0.198	1.00	0.25	5.41	(1) 2.0 (2) 3.15 (3) 2.3 (4) 2.0 (5) 2.8 (6) 3.9	1.35 1.15 1.05 1.2 1.2 0.95	1.35 1.75 1.25 1.2 1.2 0.95	1.15 1.7 1.25 1.9 1.6 1.95	
7	16.25	0.198	1.00	8.	13.5	(1) 3.9 (2) 3.8 (3) 4.7 (4) 3.7 (5) 4.4 (6) 4.6 (7) 4.6 (8) 4.5				
	16.28	Stopped			13.5					

Total ampere hours by account 13.5.

Weight of matte plates

Before heat	After heat	Loss.	Mean loss.	Meter.	Mean.
(1) 66.77	(1) 48.830	17.940	19.115	17.940	19.810
(2) 80.225	(2) 60.775	19.450			
(3) 60.445	(3) 41.360	19.090			
(4) 70.085	(4) 50.635	19.450			
(5) 58.910	(5) 39.100	19.810			
(6) 61.830	(6) 42.880	18.950			

Meter plates					
1st pair	(10)	87.595	87.545	0.050	Mean 0.033
	(12)	83.405	83.390	0.015	
2nd "	(16)	86.005	85.988	0.020	= 33 gms. in main set.
	(18)	75.017	74.970	0.047	∴ 1.213 gm. = 272 amp. hr.

13.5 amp. hrs. deposited 19.115 grammes of matte
1 " " 1.416 " " "
320 amp. hrs. deposited 1 lb. at 640,000 1 kw.

With carbon plates the average counteremf is 1.7 volts.
" CuO " " " 1.3 "

640,000 amp. hrs @ 1.3 volts = 832,000 Watt hrs = 832 Kwt hr @ 90% efficiency = 923.5 KWT hrs. mechanical. @ 0.776 ct = $7.16

640,000 amp. hrs. @ 1.7 volts = 1088,000 Watt hrs. @ 90% η = 1210. Kwt hrs. @ 0.776 ct. = $9.39

$x + y = 7289$
$2xy = 1817$
$x - y = 4444$

$2xy = 1817 \times 7289 = 13,244,113$
$4xy = 52,932,452$

$x^2 + 2xy + y^2 = 53,176,521$
$4xy \quad 52,932,452$
$x - y \quad 4444$
$197,069$

$2x = 7733$
$x = 3866.5$
$y = 3422.5$

1) $\frac{14.8}{15.5} \times 0.03 = 0.0299$ ∴ $= 1.00099$ –

Galv. 36446.5 each coil @ 66.

Legal 1 is greater ∴ Res. of 1 coil in bridge – $\frac{1.00099 \times 36446.5}{36466.5} = 1.00051$ –

As the ratio between the 2s, legal ohm does not check with that between themselves owing to the large added resistance, the link between the 2s and the 1s is supplied from the observation of the 30th on p. 19. namely that the mean 2s coil is 1.99566 of the 1s coil.

Starting from this point the ratio of the 2s being 1.000548

one 2s coil will be	1.99566×1.000274	$= 1.996198$	
the other 2s.	$1.99566 \div 1.000274$	$= 1.995121$	$1+2+2 = 4.99131$
5s	4.99131×0.996466	$= 4.973580$	$1+2+2+5 = 9.964899$
+1 10s	9.964899×1.005487	$= 10.019576$	$1+2+2+5+10 = 19.984475$
+2 10s	9.964899×1.003874	$= 10.003874$	$1+2+2+5+10+10 = 29.988349$
			$2 \quad 50$
20s	20.02275×0.99780	$= 19.978700$	49.966349
			49.977180

20 + 10 + 10 + 5 + 1 = 45.98586 of Bridge unit.

Establishment of the Resistances of a Standard Coil for Messrs Bergmann & Co. Mar. 24th 1890.

/15

Preliminary measurements.

Res. of both coils of Astatic Diff. Galv. by bridge measurement 7350 ohms
6 @ 73.5 × 0.03 × 6 = 13
7363
Leads 1
True res. of galv 7362

Passed current from 1 KHO cell through rheostat and the resistance to be compared. Adjusted galvanometer to be differential. Balance. Standard legal 1s @ 17.2°C. 1s in bridge @ 25.2°C.

Correct at 15.5
1.7 × 0.03 = 0.051 15s added to legal 1s at.

True res. 1.00051 1s. Legal.

Res. of 1s coil = $\frac{1.00051 \times 36466}{36466} = 0.99666$

Repeated test with greater care on 25th Mar. 1890.

Res. of two compounds galv coils in series 7289 –
in parallel 1817 –

Having balanced coil when in series, ascertained that 9s had to be added externally to the coil already furnished with a spool in order to balance. Removed spool which had 22.7s of 9.5. wire and replaced it after filling with 31.7s of copper wire silk covered 0.002" wound double. Instrument then balanced for both series and multiple.

Res. of coils in series by 3rd table bridge 7289 s in parallel 1817s.

1) Compared 1s in 1st table bridge with Standard Legal s. commutator, with pressure leads wound round its electrodes just above the mercury cups.

Balance with 2s added to legal s aside. Temp Std 18.8°C. Bridge 20.7°C. } Res. of 1s in bridge = 1.00044

2) Legal s against 2s (1st coil) in bridge
3619s added to 2s side

No. of Obs.	Comparison before		Temp. of Legal s	Temp. of Bridge	Res. of one coil temp. coil of Galv	Res. added for balance	} to		Ratio	Res. in terms of Legal s	
1	Legal 1s	1s in Bridge	18.8°C.	20.7°C.	36446.5	2s	Legal Std.	36466.5	1.000549 0.999451	1.00044	
2	. .	1st 2s . .	-	. .	-	3619s	2s	7268.5	1.993	1.99497	
3	. .	2nd 2s . .	.	. .	-	3622s	"	7266.5	2.00622		
4	1st 2s	2nd 2s . .	19.0°C.	. .	.	2s	2nd 2s	36466.5	1.000549		1.00066
5	1, 2, 2,	5s . .		. .	-	13s	1 2 2	36575.5	1.003567		0.996466
6	1, 2, 2, 5	10s 1st		. .	-	20s	10s	36466.5	1.005487		
7	1, 2, 2, 5	10s 2nd		. .	-	14s	2nd 10s	36585.5	1.003874		
8	10s 1st	10s 2nd		. .	.	2s	1st 10s	36485.5	0.99903		0.998363
9	10.10	20s		. .	.	8s	10 & 10	36525.5	0.99780		
10	combined 5Ω	5Ω coil		. .	.	4s	combined 5Ω	36485.5	0.998904		
11	Legal 1s	1s in Bridge	19.2	21.0°	-	2s	Legal Std.	36466.5	1.000549		

Number of Vibrations (complete) for different standard pitches

Normal	256 do.
French	258.7
German	261.6
English	270.2

Bar: observation 74·61 cm @ 77°·F

Index error ·044

74·654

Temp. corr. ·343

Corrected reading 74·997 @ 0°C.

Res. of both coils diff. galv. 5·450 T.B. 25·9°C 1 mm/cm = 2·750 each coil

Bar: observation 74·59 cm @ 70°·F 22 o'clock ~~Bar observation~~

Index error ·044

74·634

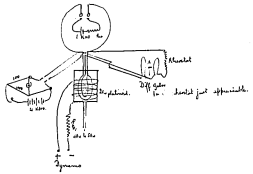
Temp. corr. ·290

Corrected reading 74·344 @ 0°C.

Mean Bar. corrected reading @ 0°C 74·33

increasing 0·002, each reading

At 10·27 current in heating coil interrupted. Res. of coils fell 0·10 before change of direction noticed by J. at Cottesmore.



$22 \times 0.00016623 = 0.0045506$ $\quad \frac{1}{1.0045506} = 0.99547$

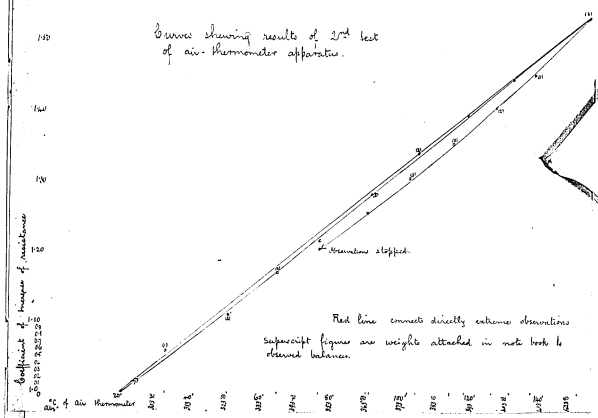
Constants of tube approx 75°; of capillary tube about 0·3 $\therefore n = \frac{75}{0.3} = 250$

$$T_{ab} = \gamma t \left\{ 1 + (V-1)(3\beta t + \kappa) \right\}$$

where $\kappa = \frac{t}{n}$ and $V = \frac{P}{p}$

res. of a to	10·130
" " b to	10·134
" " a to	20·231
2 a to b to	40·495
a to b to	20·2475
mean	20·231
interior bulb b	0·0165
other bulbs	0·015 each say.

Curves showing results of 2nd test of air-thermometer apparatus.



Experiments on the Temperature-Coefficient of Copper.

2nd trial up to 15·0°C of temp. elevation.

The only change made in the experiment was the introduction of the hand-beat differential galvo. to test quickly the resistance ratio of the two coils. This was found to be a very convenient and accurate arrangement as the following tests will shew.

At 20.30 the capillary tube was scaled. Temp. of air bath 21.16°C Bar. 74·844

Obs. No.	Time	Temp. of Hot	Temp. of Bridge	Observed res. of arm a	Corrd. 0·330 deducted	Observed res. of b or c	Diff. 0·326 deducted	Observed res. of a	Time 2·339 deducted	Balance Tr. to	Ratio Hot/Cold	Calthermometer reading	Rise above Zero	Temp. of Hot
1	20·30	21·8	24·7	10·660	10·330	10·660	10·334	20·560	20.231 20.564	17	1·00624	12·023		22·0°C
2	21·28	21·8	25·5			0·006		20·690	21·28	10	1·00367	14·986	2·963	22·0
3	·33							22·90	22·37			19·439	7·695	21·9
4	·38	21·8						23·02	23·691	8		23·000	10·977	21·8
5	·42							24·94	24·61	5	1·00183	25·970	13·947	21·8
6	·50	21·6	26·3					26·23	25·95	5	1·00183	29·618	17·595	21·8
7	·52							27·48	27·15			32·922	20·899	21·8
8	22·01							28·58	28·25			36·444	24·421	21·9
9	·10							29·66	29·33			39·664	27·641	22·0
10	·15	22·2						30·75	30·42	2	1·00073	43·032	31·009	22·1
11	·25		26·6					31·37	31·04	2	1·0000	45·103	33·080	22·2
12	·34	20·8	26·2					29·50	29·47	8	1·0030	41·180	29·157	22
13	·37							28·83	28·50	10	1·00367	38·430	26·407	21·8
14	·40							27·77	27·44			35·388	23·365	21·6
15	·45							26·74	26·41	11	1·0040	32·292	20·269	21·4
16	·51							25·75	25·42	11	1·0040	29·386	17·363	21·2
17	3·00	20·35	25·9					24·70	24·37	11	1·0040	25·962	13·939	21·0
								25·1·85	246·587			324·438	238·5·87	
								5·093	24·6·0				32··31	
								1·1·1·2·33	1·1·1·2·33					

Obs. No.	Corrected Calthermometer reading	Total run from 0°C	Coeff. r	Obs. temp. of air at time of reading	Calculated corr. temp. of air	Temp. by thermom.	Rise of temp. °C	Resistance hot	Coeff. of hot	Coeff. per hour	Res. of hot. Rise as calculated	True res. of hot. Rise	(R−1)×100=p	Correction factor
1								0·000	1·00		0·03	20·201		1·0002
2	2·950	74·311	1·000	29·46	29·46	21·6		0·00075	1·0559	0·00758			0·00029	1·00010
3	7·381	77·263	1·0597	29·46·65	30·6·35	33·35	11·75	0·0040	1·11157	·00379			0·00173	1·00047
4	10·927	81·696	1·0994	29·46·73	32·6·03	51·0	29·4	0·00046	1·1710	·00392			0·00054	1·00061
5	13·8814	85·246	1·1267	29·46·8	33·8·2	65·2	43·6	0·00075	1·2165	·00391			0·00138	1·00153
6	17·5·15	88·846	1·1870	29·46·86	35·0·0	77·0	55·4	0·00941	1·2927	·00404			0·000177	1·00211
7	20·805	91·838	1·2359	29·46·93	36·4·5	91·5	69·9	0·00812	1·3420	·00412			0·000208	1·00232
8	24·310	95·146	1·2800	29·46·98	37·7·57	104·6	83·0	0·00830	1·3964	·00457			0·000241	1·00255
9	27·516	98·637	1·3274	29·5·06	39·1·7	118·7	97·1	0·00850	1·4498	·00493			0·000273	1·00277
10	31·269	101·865	1·3705	29·5·12	40·4·5	131·5	109·9	0·00866	1·5036	·00524			0·000305	1·00297
11	32·930	105·200	1·4158	29·5·19	41·7·9	144·9	123·3	0·00876	1·5543	·00566	0·045	31·0	0·000336	1·00309
12	29·025	107·263	1·44434	29·5·22	42·6·2	153·2	131·6	0·00856	1·5467	·00394			0·000238	1·00216
13	26·287	103·360	1·3909	29·5·13	41·0·5	137·5	115·9	0·00812	1·4987	·00389			0·000260	1·00236
14	23·285	100·624	1·3544	29·5·10	39·9·6	126·6	104·0	0·00782	1·3560	·00383			0·000230	1·00156
15	20·177	97·598	1·3134	29·5·06	38·7·5	114·5	92·9	0·00809	1·3054	·00379			0·000200	1·00139
16	17·264	94·518	1·2719	29·4·98	37·5·2	102·2	80·6	0·00893	1·2565	·00372			0·000172	1·00110
17	13·937	91·637	1·2330	29·4·92	36·3·6	90·6	69·0	0·00718	1·2066	·00369			0·000138	1·00089
		88·222	1·1872	29·4·87	35·0·0	77·0	55·4							
	320·050	583·637				1440·95	273·75							
	74·311	188·976					387·2							
	394·361	394·661					1640·95							
	3·300													

The calthermometer is graduated for accuracy at 0°C its coefficient of expansion being 0·0000187 per °C (assumed by the Makers). The correction to apply to the mercury column is therefore 0·0000181 − 0·0·0000187 = 0·0001623 per °C.

No time lag could be discerned between the removal of the heat supply and the falling of the resistance. In fact the fall in resistance could be detected several seconds before the mercury column showed signs of rise.

The capillary tube was not topped, in this series.

In the case of this tube whose approximate contents was 70 c.c. with a tube whose capacity to the index was calculated to be 0.2 c.c. $n = 70/0.2 = 350$

with τ assumed at that of air in 25° + 273 = 295

and T taken at 200 + 273 = 473

The correction factor for the cooling of the index tube is $\left(\frac{473}{295}\right)^2 = \frac{223729}{103250} = 2.2$ " $\frac{1}{1.03 \times 10^{-5}} = 0.9685 \times 10^{-5}$

At present 3β will have to be taken at the usual value 0.000025

and $T = T\{1 + T(2.5 \times 10^{-5} + 0.9685 \times 10^{-5})\}\{1 - t \times 2.5 \times 10^{-5}\}$

$= T\{1 + T(3.469) \times 10^{-5}\}\{1 - t \times 2.5 \times 10^{-5}\}$

$= T\{1 + T \times 3.469 \times 10^{-5} - t \times 2.5 \times 10^{-5}\}$

t being 22 + 273 = 295

$t \times 2.5 = 737.5 \times 10^{-5} = 7.375 \times 10^{-3}$

$= T\{1 - 0.007375 + 0.000003469\,T\}$

$= T\{0.992625 + T\,0.000003469\}$

$= T\{0.992625 + T^2 \times 0.000003469$

with T = 100 + 273 = 373 $T = 375$ correction 2°

T = 200 + 273 = 473 = 477.3 " 4.3°

T = 300 + 273 = 573 = 580 " 7°

The most convenient form of the general formula is

$$\frac{T}{\text{abs}} = \frac{Pt}{p}\left\{1 - 3\beta t\right\}\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{n\tau}\right)\right\}$$ all temps absolute.

If $\tau = t$ this becomes

$$= \frac{Pt}{p}\left\{1 - 3\beta t\right\}\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}$$

Let $P = rp$

$$T = rt\left\{1 - 3\beta t\right\}\left\{1 + 3r\beta t + \frac{r-1}{n}\right\}$$

$$= rt\left\{1 + \frac{r}{n} + 3\beta t\left(r - 1 - \frac{r-1}{n}\right)\right\} \quad \text{If } 3\beta = 2.5 \times 10^{-5} = rt\left\{1 + \frac{r}{n} + 2.5 \times 10^{-5}(r - 1 - \frac{r-1}{n})\right\}$$

$$= rt\left\{\left(1 + \frac{r}{n}\right)(1 - 3\beta t) + 3\beta t r\right\} \quad \text{when } n = \infty$$

$$= rt\left\{1 + 3\beta t(r-1)\right\} \quad \text{If } 3\beta = 2.5 \times 10^{-5} = rt\left\{1 + 2.5 \times 10^{-5}(r-1)\right\}$$

$$T_{\text{abs}} = rt\left\{1 + \frac{r-1}{n} + 2.5 \times 10^{-5}(r-1)\right\}$$ if $3\beta = 2.5 \times 10^{-5}$ since $\frac{r}{n}$ is very small or.

when $n = \infty$, $= rt\left\{1 + 2.5 \times 10^{-5}(r-1)\right\}$ Let $\frac{1}{n} = K$

$rt\left\{1 + (r-1)(3\beta t + K)\right\}$

Calculation of the Correction for the Indications of an Air-Thermometer affected by expansion of the bulb and by the cooling of remote portions of included air.

Let V be the volume of the bulb at normal temperature.
" v " " " capillary tube
" V' " " " bulb at the temp. T attained.
" t " " temp. of the included air uniformly at normal.
" T " " true temperature reached uniformly in the bulb.
" τ " " " " of the air in the capillary tube.
" P " " pressure reached at temp. T (abs)
" p " " initial pressure at normal temp. τ.

Then
$$T = \frac{PV'}{\frac{p}{t}(V + v) - \frac{Pv}{t}}$$

$$= \frac{PV\{1 + 3\beta(T-t)\}}{\frac{p}{t}(V+v) - \frac{Pv}{t}} \quad \text{if } V = nv$$

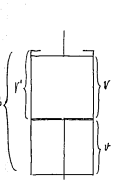
$$= \frac{Pn\{1 + 3\beta(T-t)\}}{\frac{p}{t}(n+1) - \frac{P}{t}} = \frac{P\{1 + 3\beta(T-t)\}}{\frac{p}{t}\left(\frac{n+1}{n}\right) - \frac{P}{nt}}$$

$$= \frac{P(1 - 3\beta t)}{\frac{p}{t}\left(\frac{n+1}{n}\right) - \frac{P}{nt} - 3\beta P} = \text{when } n \text{ is a large number}$$

$$= \frac{P(1 - 3\beta t)}{\frac{p}{t} - P\left(3\beta + \frac{1}{nt}\right)} = \frac{P(1 - 3\beta t)}{\frac{p}{t}\left\{1 - \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}} = \frac{\frac{Pt}{p}(1 - 3\beta t)}{1 - \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)}$$

$$= \frac{P}{p}t\left\{1 + \frac{Pt}{p}\left(3\beta + \frac{1}{nt}\right)\right\}(1 - 3\beta t) = \frac{P}{p}t(1 - 3\beta t)\left(\frac{Pt}{p}\right)^2\left(3\beta + \frac{1}{nt}\right)(1 - 3\beta t)$$

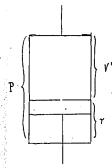
Proof: Let a cylinder be divided horizontally by a diaphragm having an orifice closed by a valve but capable of being opened at will. Let the upper cylinder be of length V' and let the piston be placed initially to enclose V. Let the lower cylinder be closed by a piston just beneath the diaphragm and a back distant v. Let the valve be closed. The temp. be t uniform throughout and the pressure p also uniform.



Then let the upper chamber be raised to the temp. T and the lower to the temp. τ. V will then increase to the limit V' which v will remain constant. The pressure Π in the upper cylinder will become $= \frac{RT}{V'}$ where R = gas const.

The pressure π in the lower cylinder " " " " " π will be the greater suppose. Now open the valve in the diaphragm. Air will descend into the lower chamber until the pressure is uniform in both and = P.

The air beneath the lower piston will now occupy a volume $\frac{v\pi}{P}$ and the volume above it occupied by air from above $= v\left(\frac{P - \pi}{P}\right)$. Had this air retained its normal temperature T, its volume would have been $v\left(\frac{P-\pi}{P}\right)\frac{T}{t}$ and the pressure above will have fallen to a degree proportional to that amount, or



$$\frac{p}{\Pi} = \frac{V'}{V' + v\left(\frac{P-\pi}{P}\right)\frac{T}{t}} \quad \therefore PV' + Pv\frac{(P-\pi)T}{Pt} = \Pi V'$$

$$\therefore PV't + P^2vT - Pv\pi T = \Pi PV't$$

$$\therefore PV't + Pvt - \pi vT = \Pi V't$$

Eliminate π and Π. $\frac{\Pi V'}{P} = \frac{pV}{t}$ & $\frac{\pi v}{P} = \frac{pv}{t}$

$\therefore \Pi = p\frac{V}{V't}T$ $\pi = p\frac{v}{t}$

$$\therefore PV't + Pvt - \frac{pvvT}{t} = \frac{pVTt}{t}$$

$$\therefore PV't + Pvt - \frac{pvTt}{t} = \frac{pVTt}{t}$$

$$T(Pvt - pvt - pVt) = -PV't\tau$$

$$T\{pt(V+v) - Pvt\} = PV't\tau$$

$$T = \frac{PV't\tau}{pt(V+v) - Pvt} = \frac{PV'}{\frac{p}{t}(V+v) - P\frac{v}{t}}$$

Required the Winding for two new cores on the present form of Electromagnetic Rockdrill.

The new magnets are to be 8" (20·3) long and 3·25" (8·22) in diam. The surface of each when wound to a depth of ¼" will be $\pi \times 11{\cdot}2 \times 20 = 704$ sq. cm. and allowing 10 per watt = 70 watts on each. If operated from a P.D. of 50 volts all 3 coils in series the P.D. on each = 16·67 and the current will be over 1. amp. As this will be excessive for the central coil it will be better to employ 20 sq. cm. per watt = 35 watts per coil = $\frac{35}{16{\cdot}67} = 2{\cdot}1$ amp. The res. of each coil will be $\frac{16{\cdot}67}{2{\cdot}1} = 7{\cdot}94\Omega$ (hot) = $\frac{7{\cdot}94}{1{\cdot}12} = 7{\cdot}052\Omega$ cold. The winding space is

$$20 \times \frac{\pi}{4}(11{\cdot}2^2 - 8{\cdot}2^2) = 15{\cdot}708\,(125{\cdot}44 - 67{\cdot}24) = 15{\cdot}71 \times 58{\cdot}2 = 914{\cdot}4 \text{ c.c.}$$

$$d = -0{\cdot}02 \pm \sqrt{\left\{0{\cdot}0004 + 0{\cdot}00153\sqrt{\frac{914{\cdot}4}{7{\cdot}05}}\right\}}$$

$$+ 0{\cdot}00153\sqrt{130{\cdot}1}$$

$$+ 0{\cdot}07745$$

$$\sqrt{0{\cdot}01785}$$

$$+ 0{\cdot}1336$$

$$= 0{\cdot}1316 \text{ mm.} = 0{\cdot}052'' = \#16 \text{ B.\&S.} \text{ or } \#18 \text{ B.W.G.}$$

#18 B.W.G. has 1·69 lbs. per ohm = 11·83 say 12 lbs. of #18 B.W.G. magnet wire on each core.

Test of the specimens of Safety Conduit Tubing that have been submerged in a tank since 11th Jany. 90

25. II. 90.

Bonet and Simple minor hipot galv. not solder.
#1 Apollo cable no. S. 100,000 – 187 diam.

Specimen #1	⅝" diam.	50 cells no S.	157 – 162 +	about 4 a abs.	
# 2	⅝"	bad 1	17 + 20 –		
# 3	1½"	50	345 – 350 +		2·5Ω
# 4	·3"	short piece 50	18 ±		50Ω
		but bad			

Tried to improve these readings by recovering the ends of these tubes with paraffine wax.

Succeeded with #1 in bringing deflection down to 110 ± = 8·5 Ω abs., but not with the other. On careful examination the faults were found to exist at particular places in each tube, as following example will show:—

No 3. in air after coating with paraffine wax on ends.
Drawn slowly through wet cotton waste in cat, local deflection.
Dried again and submerged.

1st ½ d.	submerged in tank	50 cells no S.	± 3 diam
1st 3½d.	–	–	± 70 –
almost wholly	–	–	+ 350 – of only above water, showing fault not in the seal.

Sent following report to Mr. E. H. Johnson of Edison & Boston.
"Specimens previously reported on now offers eight and half meghm
Some specimens failing others very fair. All submerged for seventy days.

Test of same specimens on 26th April 1890.

Specimen #1 by bridge ⅝" diam. 2·5Ω
short piece 1" in cat – 0·6Ω

Other all bad.

But of one piece of 1¾" I found it to contain 250 c.c. of clear water. Ascertained that the insulation was bad all through this piece although the section looked good. Sent a sample and a report to Mr. Johnson.

No correction is made to the appr res of the galv. coils for temp. because all the resistances employed are affected by w. like error.

		Sum
1ω in bridge balance as unity	1·000 000	
2ω #1 . . .	1·995 39	
2ω #2 . . .	1·995 39	1·991 32
5ω	4·973 74	9·965 06
10ω #1 .	10·021 96	19·9 87 02
10ω #2 .	10·011 12	29·9 98 14
20ω	20·016 75	50·0 14 89
50ω	49·974 13	99·989 02

20 + 10 + 10 + 5 + 1 = 46·02257

1ω @ 15·5 = 0·0003 × 7·4 = 0·00222 at 22·9°C

= 1·00222ω

1·00222 × 0·999185 = 1·001463 ω

If s be the res. of the std. ω at a given temp.
Then the res. of the bridge unit = 0·999 32 s.
and the " " " 46 ω = 46·0047 × 0·999 32 s. = 45·97345 s.

The res. required being r
" " of our galv. coil g
" " for balance x

$$\frac{g+x}{g} = \frac{r}{45\cdot97345\,s}$$

$$x = \frac{gr}{45\cdot97345} - g$$

$$= g\left(\frac{r - 45\cdot97345\,s}{45\cdot97345\,s}\right)$$

or

$$\frac{g}{g+x} = \frac{r}{45\cdot97345\,s}$$

$$\frac{g+x}{g} = \frac{45\cdot97345\,s}{r}$$

$$x = g\left(\frac{45\cdot97345\,s}{r} - 1\right)$$

$$= g\left(\frac{45\cdot97345\,s - r}{r}\right)$$

Comparison of Bridge B with Legal Ohm.

30 III. 90

Legal ohms immersed in water. Temperature very fairly uniform for several hours. Actual Diff. galv. quite differential bo added to spark side + subtd.

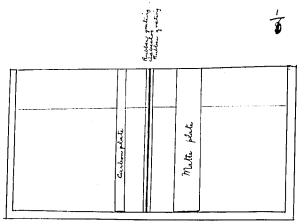
No. of Obs.	Temp. of Standard Ohm	Res. of Standard Ohm	Temp. of Bridge	Resistance compared		Balance res. added	to the	Res. of Galv. coil on one side	Res. of added side	Ratio	Res. of bridge in ω
1	23°C.		22·9°C	Legal 1ω	1ω in this {2 in parallel	3ω	10·50	Legal Std.	3677·5	3680·5	0·999185	1·00000
2	Std. Ohm			" 1ω				" "	"	3688	0·997017	0·997830
3	#1			" 1ω	1ω . 6.*	2ω		" "	"	3680·5	"	
4				2ω #1	2ω #2	1ω		2ω #2	"	3678·5	1·000271	(1·995739) #2 (1·995739) #1
5				1+2+2	5ω	13ω		1+212	"	3690·5	0·994477	4·973714
6				1+2+2+5	10ω #1	21ω		10ω	"	3698·5	1·005710	10·021196
7				1+2+2+5	10ω #2	17ω		10ω	"	3696·5	1·004622	10·011112
8				10ω #1	10ω #2	3ω		10ω #1	"	3680·5	1·000816	(1·000883 by wt from 1-7)
9				10ω #1	20ω	6ω		10ω #1	"	3683·5	0·999104	
10				Σ 50	50	3		Σ 50	"	3680·5	0·999185	

* Change made here under condition of connections necessary to throw the 2 2ω coils in parallel.
The 2 2ω coils in parallel test 0·997017 by ω and the 1ω coil test 0·999185 by ω
so that " " " " " 0·997830 1ω coil
" " test 2ω " supposed equal 1·99566
one (#2) 2ω = 1·000271 of the other (#1)
#2 = 1·0001355 × 1·99566 = 1·995930
#1 = 1·99566 ÷ 1·0001355 = 1·995389

24th Comparison of results of tests on two different occasions 30th March

No.	Coil	Temp.	Res. added to coil	Ratio to Bridge 1ω	Res. of 46ω		Coil	Temp.	Res. added	Ratio to Bridge 1.	Res. of 46ω	Mean Res. of 46ω
1	1ω	20·7°C		1			1ω	22·9°C		1.		
2	#1 2ω			1·995121			2ω #1			1·995739		
3	#2 2ω		+2	1·996198			2ω #2		+1	1·995993		
4	5		−13	4·97358	45·91516		5ω		−13	4·973714		
5	#1 10		+20	10·019576			10ω #1		+21	10·021196	46·02257	46·00471
6	#2 10		+14	10·008597 .003174			10ω #2		+17	10·011112		
7	20		−4	19·984110 19·987600			20ω		−6	20·01675		
8	50						50ω			49·97413		

At temp. of 22·9°C. the 1ω in bridge = 0·999185 of legal ω at same temp.
20·7°C " " " " = 0·994451
Mean = 0·999318



Longitudinal section of bath.

If A be the area of matte in sq. ft
" d " " density of current in amp. per sq. ft
Ad will be the total current flowing and
$\frac{640000}{Ad}$ = time in hours required to dissolve 1 ton.
" r be the res: of one sq. ft
$\frac{r}{A}$ = total resistance
and Ad^2r = C^2R = total rate of working
640,000 dr = total number of Watt hours
640 dr = " " " " " electrical
800 dr = " " " " " mechanical @ 80%

The res: is 0.234 for ⅓ sq. ft = 0.157 " for sq. ft
126 d = total number of Watt hrs mechanical for this bath
97.8 d ditto " " " ditto " " " "
$8 d appx.

Experiment upon Electrolysis of Matte.

A large bath of NaCl solution in water was prepared of dimensions shown, and having at its center a transverse partition of asbestos 0.25" (1/40") thick. Sp. g. of solution 1.16 @ 17°C. The matte plate was a casting 11" (27.9) × 11" (27.9) × 2.25" (5.7) = 272 c.in. (4460 cc) weighing 700 oz (26.5 kgm) sp. g. of 6.05.

The matte plate cracked up and disintegrated so rapidly that it spoiled the test. A copper voltameter was in circuit. The depth of solution was 8" (20) so that the area of matte exposed was about ⅓ of 1 sq. foot, and the distance between the carbon and matte plates was 4½" (11.4). The carbon plate fitted the bath with fair accuracy and was 1" (2.5) thick.

The following observations were made as soon as the current had fairly started.

No of Obs:	Time	Obsch	Amperes	Lamps	PD across bath	Res: by measure	PD across 1 ohm res:	EMF	Amperes per sq foot	Approximate cost for consuming 1 ton	Total cost per ton
1	15.0	0.415	2.08	4	1.65	0.234	0.487	1.16	3	$ 3.	$ 10.35
2	.05	0.590	2.95	6	1.95		0.690	1.26	4.5	4.60	11.75
3	.07	0.752	3.78	8	2.20		0.884	1.32	5.67	5.55	12.85
4	.09	0.915	4.60	10	2.37		1.08	1.29	6.9	6.75	14.10
5	.11	0.53	5.3	12	2.53		1.24	1.29	7.95	7.77	15.12
6	.15	0.59	5.9	14	2.70		1.38	1.32	8.85	8.65	16.00
7	.17	0.645	6.5	16	2.82		1.52	1.30	9.75	9.53	16.88
8	.18	0.705	7.1	18	3.0		1.66	1.34	10.65	10.42	17.77
9	.19	0.763	7.6	20	3.1		1.78	1.32	11.4	11.17	18.52
10	.20	0.815	8.2	22	3.2		1.92	1.28	12.5	12.22	19.57
11	.22	0.851	8.5	24	3.32		1.99	1.33	12.75	12.46	19.81
12	.22	0.91	9.1	27	3.48		2.13	1.35	13.65	13.35	20.70
13	.23	0.85	8.5	24	3.32		1.99	1.33	12.75	12.46	19.81
14	.24	0.815	8.2	22	3.24		1.92	1.32	12.3	12.02	19.37
15	.25	0.766	7.7	20	3.12		1.80	1.32	11.55	11.30	18.65
16	.26	0.705	7.1	18	3.0		1.66	1.34	10.65	10.41	17.76
17	.27	0.641	6.4	16	2.82		1.50	1.32	9.6	9.39	16.74
18	.28	0.588	5.9	14	2.71		1.38	1.33	8.85	8.65	16.00
19	.29	0.527	5.3	12	2.55		1.24	1.31	7.95	7.77	15.12
20	.30	0.445	4.5	10	2.37		1.05	1.32	6.75	6.60	13.95
21	.31	0.371	3.7	8	2.2		0.87	1.33	5.55	5.43	12.78
22	.32	0.296	2.2	6	2.0		0.7	1.30	4.5	4.40	11.75
23	.34	0.217	2.2	4	1.8		0.52	1.28	3.3	3.23	10.55

640,000 amp hrs: dissolve 1 ton of Matte.
at 1.33 volts = 853000 Watt hrs
= 853 kilowatt hrs electrical
= 947 " " mechanical @ 90% eff. @ 0.776 = $7.35

Adjustment of a Standard 46·46ω Coil for Messrs Bergmann &c:

1. IV 90.

#1 coil in water up to within 1 cm of neck. Temp. of water 19.42

Res: of galv: 7367ω by bridge w/o/ms T.B. 25·5°C leads 2ω = 7365ω.

allowing for excess of bridge temp. each component coil = 3685ω

Temp of standard bridge 23·4°C.

46ω unplugged in the bridge will offer 45·973 × 1·00237 = 46·0822ω

46·46ω @ 70°F (21·1°C) = 46·155ω @ 19.4°C

∴ res: to add to coil side = $3685\left(\frac{46\cdot155 - 46\cdot082}{46\cdot082}\right) = 5\cdot8\omega$

Coil adjusted until balanced at 6ω

#2 coil similarly situated. Final measurement

Res. of each component galv coil 3685ω. Temp. of water surrounding coil 20.95

46ω unplugged in the bridge = 45·973 × 1·002446 = 46·0865

46·46ω @ 21·1°C = 46·4059ω @ 20.5

∴ res: to add to ~~bridge~~ coil side = $3685\left(\frac{46\cdot4059 - 46\cdot0865}{46\cdot0865}\right) = 25\cdot6\omega$.

Coil adjusted until balance between 25 + 26ω.

Thermometer used was Standard #1.

Check by Bridge on 4th table.

Coil #1 @ 20.9°C. 1000/100 leads

48·45ω
2·02
46·43 @ T.B. 27·5
·01
46·44ω = coil @ 21·0°
·03
46·47ω @ 21·1°C.

Coil #2 @ 21·1°C 1000/100

48·47ω
2·02
46·45ω @ TB 27.5
·01
46·46ω @ 21·1°C.

Calculation of wire for new Electrodynamometers

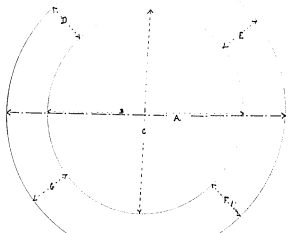
In the present dynamometer 70 turns give 360° with 17·5 amp. For 1000 volts the current should not exceed 20 milliamperes say 17·5 milliamperes so for the fact there must then be 70.000 turns instead of 70. The thickness of the coil is 1·25" and its depth 0·5". The diam of the present wire (covered) is 0·11". It will then be necessary to use the finest silk covered wire for the interior bobbin.

For 100 volts the current should not exceed 50 milliamperes or $\frac{1}{350}$th of that in the present coil. The diameter of the wire should then be reduced 18 times or 0·004" but as this coil will have enormous self induction, it will be necessary to use stronger current and external resistances.

The highvolt dynamometer can have a diam of 0·033" covered = 0·030" # 22 wire B.W.G. and the low volt dynamometer 0·055" covered = 0·048" # 19 wire B.W.G. d.c.

The external coil of the voltmeter for 1000 volts will be 2 layers of 10 turns.

The external coil of the voltmeter for 50 volts will be 5 turns in 1 layer of



Permeability Measurement of Iron Samples.

Ring of polished Mitis iron, and a larger ring of cast iron supposed to contain 1/10 part of air by weight in 1/14 of metal or 12.287.

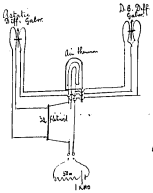
No.	Composition	A	B	C	D	E	F	G	Mean DEFG.	Wt in air	Wt in H2O	Volume by H2O	Volume by calculation
1	Iron	25.2	~~25.0~~	16.9	3.15	3.1	3.2	3.2	3.163				
2	Mitis	18.2	16.05	16.05	1.12	1.123	1.17	1.125	1.122	4.079	3.529	550	544.85

No.	Total No. of turns	Total primary turns	Total secondary turns	Mean circumference cms.	Primary turns per cm.	Area of circle section sq. cms.	
1	1408	1025	~~1080~~	69.28	14.79	7.858	
2	1053	~~818~~	335	53.80	~~1.25~~ 15.21	1.019	7.4

No. of Obs.	(1) Time	(2) Sec. galv.	(2) Ballistic	(2) Current amp.	2) No. of Obs.	2) Mean throw	2) Probable error	2) Res. of galv. cct.	2) Res. in main cct.	2) Total res. in sec. cct.	2) $\frac{2\times 10^{10}}{2\times 2\pi}\times\frac{0.05}{3}$	H	φ
1	14.15	14.07	~~0.019~~	0.190	5	29.7	± 0.7	20,200	–	20,200	~~2.4×10⁻⁴~~	$\frac{2.3\times 10^{-3}}{5.19}$	3.811×10⁻³
2	27	26.15	0.061	0.172 0.309	7	57.0	± 0.6				7.776×10⁻³	4.11	7.31
3	55		0.120	0.606	6	77.0	± 0.4					10.12 8.09	9.88
4	15.08		0.244	1.08	4	92.5	± 0.25					11.11 14.42	11.87
5	17		0.202	1.526	7	44.1	± 0.5					25.38 26.38	12.66
6	30		0.51	2.576	6	48.8	± 0.5					32.13 34.39	14.01
7	38		0.76	3.84	4	57.1	± 0.4					41.10 51.29	14.67
8	45		0.025	5.178	2	55	± 1.6					62.10 69.7	15.79
9					3	61.33	± 2.6						15.40
10	48		1.615	8.16	2	128.5	± 1.2					127.0 107.9	16.48
11	56		2.39	12.07	2	135	± 1.7					132.0 161.1	17.32
12	1.00		3.210	1.061	3	92.7	± 0.5					17.41 14.16	11.89

No. of Obs.	1) No. of Obs.	1) Mean throw	1) Probable error	1) Res. of galv. cct.	1) Res. of main cct.	1) Total res. in sec. cct.	1) $\frac{2\times 10^{10}}{2\times 2\pi}\times\frac{0.05}{3}$	H	φ	1) L	μ	3) L	3) μ
1	6	16.3	± 0.4	20,200	0	20,200	6.801×10⁻³	3.53	1,930	233	66	3741	1175
2	7	77.2	± 0.5				8.166×10⁻³	5.76	8,664	1103	192	7176	1860
3	7	204.4	± 1.4				= 5.552×10⁻³	11.27	22,940	2920	259	9,700	1889
4	6	322	± 3.0					20.08	36,140	4600	229	11,650	8.08
5	5	172.3	± 0.2		25,000	45,200		28.37	43,270	5507	194	12,430	6.80
6	6	221.3	± 1.4					47.90	55,570	7072	148	13,750	2.00
7	6	249.9	± 1.2					71.4	62,720	7982	112	14,400	2.87
8	4	275	± 2.8					96.28	69,060	8790	91.3	15,500	1.78
9												15,120	2.19
10	2	321	± 10					151.75	80,600	10260	67.6	16,180	1.18
11	2	225	± 2.4		50,000	70,200		224.4	87,750	11,170	49.8	17,000	1.49
12	3	329	± 2.6					19.73	36,930	4700	23.8	11,670	1.86

No. of Obs.	EME	Body	q.	No. of Obs.	Before Inc. Mean throw	Prob. error	No. of Obs.	After Dec. Mean throw	Prob. error	Accepted mean throw	value of 1 div. in q.	
1	1.431	1f	1.431×10⁻⁷	6	173.7	± 0.16	10	176.8	± 0.6	175.2	8.166×10⁻⁷	
2				~~10~~	~~176.8~~	±						



Res: of Ast. Galvo both coils 7205 ω. T.A. 18°.0
heads
7203 ÷ 2 = 3601.5

. . D.A. . both coils 5332
2
5330 ÷ 2 = 2665.

Both galvanometers differentiated to observation.

Barometer reading at time of reading 76·22
index corr ·0444
76·2644 @ 20·5

0·0000017 × 20·5 = 0·000349
76·2644 + 1·000349 = 76·999
Temp. corr 0·265

Res: of Ast. Galvo. after test 7261 ω.
heads 2
7259
coil cut 3629·5 ω.

Barometer reading 21·30 76·27
·044
76·314 @ 21·1°
·269
76·045 @ 0°C

0·0001623 × 15·6 = 0·0025323
0·0001623 × 17·8 = 0·0028890
Mean 0·0027111

$k = \frac{1}{200} = 0·005$

$t = 300$

$\beta = 2·5 \times 10^{-5}$

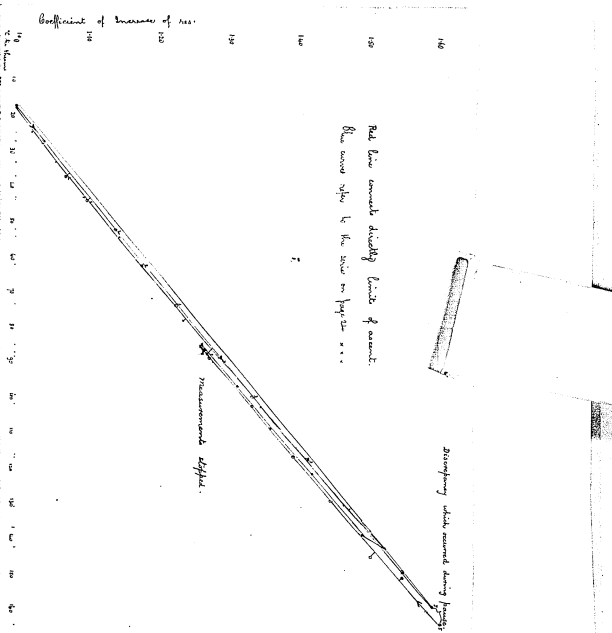
$\beta t = 7·5 \times 10^{-3} = 0·0075$

βt corr 0·0115

Res: of galvo at close of test 7261
2
2)7259
3629·5

3617·25 × 21 = 75962·25

1·605	1·255
1·597	1·263
1·601	1·262
1·601	1·262
4)6·404	4)5042
1·601	1·261



Sunday) 23 IV 20

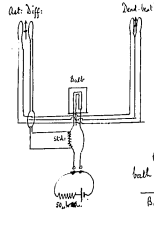
Experiments on the Temperature-Coefficient of Copper.

In this series, the measurements were made principally with two differential galvanometers, one controlling the two halves of the enclosed coil, and the other comparing one half with a platinoid fixed resistance. Readings were taken at the limiting points by bridge as check. Tubes not tapped in this series.

Temp. of oil bath at time of sealing 17.2°C.

No. of Obs.	Time	Temp. Hg.	Temp. from Bridge	Observed reading a.b.c.	Same with lead 0.3175 subtracted	Observed reading b.c.	Same for lead 0.3175	Observed reading a.b.	Same for lead 0.332	Balance reading added to 10.	Ratio log.	Calibration Reading	Temp. Hg. cal.
1	20.33	15.6°		10.230	9.9115	10.230	9.9125	20.11	19.788 = 19.824	17.	1.0067	12.128	15.6
2	.38					1.000						15.286	15.7
3	.40											17.212	15.8
4	.42											19.114	15.9
5	.45											21.278	16.0
6	.49											23.832	16.1
7	.52			1			1		1				
8	.54			0			0		0			26.826	16.2
9	21.00	16.4°		0			0		0			30.274	16.3
10	.07			5			5		5	10.	1.0044	33.654	16.4
11	.11				1.601							38.030	16.6
12	.19											41.602	16.8
13	.25											45.960	17.0
14	.30			16.23	15.911	16.16	15.842	32.01	31.688	15.	1.006	50.212	17.2
15	.31											49.264	17.4
16	.33											46.764	17.5
17	.36	17.8°										44.230	17.6
18	.41											43.054	17.8
19	.47											37.750	17.8
20												34.074	17.8
21				12.86	12.461	12.84	12.522	25.30	24.983	10.	1.0044	30.580	17.8
22					(1.255 mh)		(1.283 mh)		25.018 25.068 (1.262 mh)			29.758	17.8
												29.782	
												24.685	
												437.074	

No. of Obs.	Corrected Calibration Reading for lead	Coeff. r	(T-1)(Calib.)	Correction Factor	Corrected Normal abs. temp.	Corrected abs. temp. at Saturation	Temp. by air thermo.	Rise of temp. by air thermo.	Res. for balance	Res. in G. cal.	Ratio:	Ratio by bridge	Coeff. for 1° rise
1	0.000	1.0	0		290.2	290.2	17.2		7300	10,901.5	1.000		0.00809
2	3.158	3.150	1.04114	0.0005	290.4	302.4	27.4	10.2	6900 (a)	10,503	1.038 (a)		0.00373
3	5.182	5.170	1.08803	0.00078	290.5	310.3	37.3	20.1	6580 (a)	10,184.5	1.0704 (a)		0.00358
4	6.956	6.942	1.12167	0.001052	290.5	317.1	44.1	26.9	6300 (a)	9,906	1.1005 (a)		0.00373
5	9.150	9.136	1.1201	0.001381	290.6	325.5	52.5	35.3	5950 (a)	9,557.5	1.1406		0.00398
6	11.704	11.693	1.1536	0.001766	290.7	[illegible]	[illegible]	[illegible]	5650 (a)	9,259	1.1774		0.00393
7	14.498	14.488	1.1874	0.002218	290.9	347.0	73.7	56.5	5280 (a)	8,905	1.2261		0.00401
8	18.146	18.135	1.2261	0.002738	291.0	366.3	93.3	76.1	4900 (a)	8,513	1.2706		0.00386
9	21.326	21.320	1.2706	0.003217	291.2	372.7	99.7	82.5	4550 (a)	8,164.5	1.3352		0.00415
10	25.92	25.921	1.3349	0.003909	291.3	390.3	117.3	100.1	4100 (a)	7,716	1.4128		0.00424
11	29.474	29.475	1.3848	0.004448	291.5	404.3	131.3	114.1	3770 (a)	7,387.5	1.4757		0.00469
12	36.832	36.832	1.4333	0.005558	291.8	432.8	159.8	142.6	3220	6,839	1.5940	1.601	0.00416
13	38.284	38.285	1.4495	0.005747	291.9	437.8	164.8	147.6	3170	6,790.5	1.6054	1.601	0.00401
14	37.135	37.144	1.4374	0.005604	291.8	434.0	161.0	143.8	3250 (a)	6872	1.5863		0.00407
15	34.636	34.644	1.4545	0.005226	291.7	424.3	151.3	134.1	3400	7023.5	1.5521		0.00417
16	32.100	32.107	1.4345	0.004997	291.6	418.8	145.3	128.1	3620	7245	1.5047		0.00394
17	28.926	28.935	1.3796	0.004365	291.5	402.3	129.3	112.1	3900	7526.5	1.4484		0.00400
18	25.622	25.627	1.3363	0.003867	291.3	389.2	116.2	99.0	4200	7828	1.3926		0.00366
19	21.946	21.951	1.2880	0.003313	291.2	375.1	102.1	84.9	4550	8179.5	1.3328		0.00319
20	18.472	18.482	1.2419	0.002782	291.0	361.4	88.4	71.2	4930	8561	1.2734		0.00284
21	17.604	17.591	1.2314	0.002661	291.0	358.3	85.3	68.1	5010	8643	1.2613	1.261	0.00283
	37.07	37.07							5010				
		12000							105 30	17,649 1			
									169 22				
									174,492				



two inserted permanently on spool side of Act. Diff: Galv for balance in parallel. Both in series differential with both galvs.

Res: of Act: Diff: @ 19°C before heat.

After heat taken @ 20°C

7240	T.B. 19.5°
2	
7238 ÷ 2 = 3619	
7295	T.B. 20.0°C
2	
7293 ÷ 2 = 3646.5	

Res: of H.B. D.B. Diff before heat

5360	
2	
5358 ÷ 2 = 2679	

Capillary tube opened + recalibrated at 21.0 Temp: of oil bath by Nat. Std: Thermom: 17.8°C.

Bath by Nat. Std: Thermom: 17.8°C.

1 H.H.O cell working through 50ω + standard platinum res.

Barometer at time of heating

	75.52
Index error	.0344
	75.5644 @ 21.7°C
	.279
	75.285 @ 0°C

0.00017 × 21.7 = 0.003689
× 75.56 = 0.279

Barometer at calibrating readings 22.24 o'clock

	75.52
	.0344
	75.6244 @ 22.2
	.285
	75.339 @ 0°C

0.00017 × 22.2 = 0.00377
× 75.62 = 0.285

Same reading at close of heat.

Some slight p.d. when testing current was off, observed on diff. galvo. The zero was reset at nearly every observation and taken to the fixed it did not exceed 10 divs: and was supposed to be of thermoelectric origin.

Each div: of diff: galvo scale corresponds to about 0.7ω change of res:.

Full deflection on H.B. D.B = 250 ±. reading to 1ω.

Current strength in main circ: as usual about $\frac{0.75}{30 + 30 + \frac{50}{2}}$ = 7.5 bbb m-amp. Rate

Current strength in heating coil circ: 2 to 3 amperes.

No globule of mercury in right-angle tube.

0.0001623 × 17.2 = 0.002791
0.0001623 × 19.3 = 0.003132

3βt + H = 0.0115

The curve of results is added to the sheet on the preceding page.

Sept. 29. III. 90

Experiments on the Temp. Coeff. of Copper.

In this series the two differential galvanometers were again used under very favourable conditions, and the heat was considered a good one. The capillary tube was tapped before each observation, like a barometer to overcome friction.

No. of Obs.	Time	Temp. of Hg.	Temp. of Room & Bath	Obs. res. in ω	Corrected res. Index deducted ÷ 320	Obs. res. in ω	Corrected res. Index deducted ÷ 0.3195	Obs. res. in ω	Corrected res. Index deducted ÷ 0.3264	Rate of change	Balance Thermometer read. when added Hg	Ratio ÷ 10	Calibration Reading	Temp. of Hg. Nat. Std.
1	21.28	17.2	17.88 (int. 18.4°C out air 19°C)	10.230	9.910	10.225	9.8055	20.050	19.726 = 19.8155 + 0.0895		24ω	1.009	11.900	17.2
2	.40					Temp. of Bath 21.8°C.							13.684	17.2
3	.43					1.0008							15.890	17.2
4	.47	17.2								1.5246 ω			18.514	17.2
5	.52													
6	.55	17.5									15ω	1.006	21.366	17.3
7	22.00		19°C air 20.4 int.										24.318	17.4
8	.05									1.5425 ω	13ω	1.005	27.304	17.5
9	.10	17.6											30.200	17.6
10	.16	17.8											33.602	17.7
11	.24									1.548 ω	13ω	1.005	37.400	17.8
12	.34	18.8											40.638	18.3
13	.45			15.6400	15.320	15.600	15.280	30.850	30.526 ÷ 30.600		10ω	1.0038	43.754	18.8
14	23.02		20°C air int. 21°C.			1.002					8ω	1.003	45.492	19.0
15	.06													
16	.11	19.3											42.342	19.1
17	.15	19.3	19.2°C air										38.432	19.3
18	.17												34.956	19.3
													32.059	19.3
19	.19										20ω	1.0075	28.972	19.3
													26.0422	
													2342	
		326.722											326.722	

No. of Obs.	Rise of Calibration ÷ 10	Rise at 0°C.	θ-θ₀	(θ-θ₀)	(θ-θ₀)(θ+θ₀)	Correction Factor for Hg temp	Corrected Normal Atm. temp	Corrected Atm. temp at obs.	Temp. °C by Thermometer	Rise of °C by temp by thermometer	Res. for Balance	Res. in Galv. ωω	Ratio	θ-θ₀ for ωω	Res. of Galv. ωω
						1.002791	290.8	290.8	17.8	0	(-) 48.05 ω	5.64	1.0000		3619
1	0														
2	1.784	1.779	1.0236	0.00027	1.002791	290.9	297.69	289	7.1	1730 (-)	3349	1.0215	0.00303		3619
3	3.990	3.979	1.0528	0.000667	1.002791	291.0	306.14	334	15.6	1560 (-)	5180.5	1.0551	0.00353		3620.5
4	6.614	6.595	1.0876	0.000007	1.002791	291.1	316.6	436	25.8	1370 (-)	4992	1.0954	0.00369		3622
5	9.466	9.440	1.1254	0.001422	1.002891	291.2	327.7	547	36.9	1150 (-)	4773.5	1.1468	0.00396		3623.5
6	12.418	12.383	1.1837	0.002113	1.002824	291.4	344.9	719	54.1	970 (-)	4595	1.1991	0.00552		3625
7	15.404	15.360	1.2040	0.002268	1.002840	291.5	351.0	780	60.2	805 (-)	4431.5	1.2355	0.00310		3626.5
8	18.400	19.364	1.2435	0.002504	1.002856	291.6	362.6	896	71.8	600 (-)	4228	1.2955	0.00405		3628
9	21.702	21.640	1.2974	0.003305	1.002872	291.8	375.7	1027	84.9	435 (-)	4064.5	1.3482	0.00401		3629.5
10	25.000	25.427	1.3376	0.003882	1.002889	291.9	390.4	1174	99.6	250 (-)	3881	1.4120	0.00402		3631
11	28.738	29.652	1.3804	0.004371	1.002970	292.1	403.2	1302	112.4	105 (-)	3737.5	1.4674	0.00429		3632.5
12	31.854	31.757	1.4217	0.004850	1.003001	292.2	415.4	1424	124.6	-35 (-)	3669	1.5245	0.00420		3634
13	33.592	33.488	1.4447	0.005114	1.003093	292.3	422.3	1493	131.5	-97 (-)	3732.5	1.5501	0.00493		3635.5
14										-75	3712	1.5405			3637
15	30.442	30.348	1.4031	0.004635	1.003310	292.2	410.0	1370	119.2	+50 (-)	3688.5	1.4893	0.00405		3638.5
16	26.532	26.449	1.3512	0.004039	1.003132	292.0	394.55	1215	102.75	+230 (-)	3870	1.4209	0.00407		3640
17	22.056	22.984	1.3053	0.003511	1.003132	291.9	381.2	1082	90.4	400 (-)	4041.5	1.3604	0.00397		3641.5
18	20.158	20.095	1.2668	0.003046	1.003132	291.7	369.5	965	78.7	545	4188	1.3133	0.00381		3643
19	17.072	17.019	1.2260	0.002599	1.003132	291.6	357.5	845	66.7	715	4359.5	1.2622	0.00393		3644.5
	326.722						6817.64	1603.65	1252.25						
								44.14	320.4						
								6817.64	1603.61						

0.66238
0.67657
0.69487
0.72558
0.75409
0.78849
0.81834
0.85508
0.89241
0.93558
0.97119
1.00663
1.02668
1.02036
1.08646
0.94016
0.90103
0.86486
0.83594

The mitis ring was rewound and an error in the counting of its previous winding corrected.

The two rings tested were connected in series and the galvanometer connected with one or the other.

The throws with standard cell and condenser were taken three times with the following results — 1 Cleck cell 1 + 52.

No. of Series	EMF	Q abs.	No. of Throws	Mean Throw	Approx. Probable error E	Time of Obs.	Weight estimated	Mean	Value of 1 throw				
1	1.4431	1.4431×10^{-7}	11	181.5	±0.4	9.20	1	181.5	ob Q				
2	1.4431	1.4431×10^{-7}	8	182.3	±0.2	15.0	3	546.9	181.3	7.888×10^{-10}			
3	1.429	1.429×10^{-7}	9	178.1	±0.5	16.0	1	178.1					
								906.5					
								181.3					

$$\frac{7.888 \times 10^{-10}}{2 \times 335} \times 1000 = 1.1773 \times 10^{-12} \times 1000 = 1.1773 \times 10^{-9}$$

$$\therefore \frac{425}{5} \times d \times r \times 1.1773 \times 10^{-9} = \varphi$$

$$\frac{7.888 \times 10^{-10}}{2 \times 393} = 1.0027 \times 10^{-12}$$

Measurement of the Permeability of certain samples of iron cast at Schenectady and one of Mitis.

No.	Temperature by circling	A	B see page 22 facing	C	D	E	F	G	Mean EFG	Area of X section	Weight in air	Weight in water	Vol. by weight	Vol. by formula	Sp. g.
1	Mitis	18.2	16.05	16.05	1.12	1.123	1.12	1.125	1.122	1.019	4079	3529	55	54.8	7.4
2	Good cast	24.25		3.35 3.1	3.25	3.15	3.5	3.2	3.26	8.34-7	4001	2428.6	57.54	57.3	6.96

No.	Time on 1st Layer	Time on 2nd Layer	Time on 3rd Layer	Time on 4th Layer	Total time Running	Total time Standing	Total time Accumulated	Mean time of putting on					
1	335	328	274	231	1168	838	335	53.80	18.48				
2	393	193	174	–	750	357	393	69.28	5.152				

No. of Obs.	Time	Galvo.	Amperes	No. of Throws	Mean Throw	Approx. probable error	Res. of Galvo at	$\frac{G+S}{S}$	Res. of Galvo at Intrd.	φ	L	H	μ	Thousand Difflu.
1	10.22.	3'.45"		7	37.2	± 0.6	5250	1	5250	2.320×10^{-12}				
2	42	6'.5'		7	66.2	± 0.4	"	"	"	2.2580×10^{-12}				
3		13.15'		8	278	± 3.3	"	-	"	4.0092×10^{-12}				
4		16.30'		7	675	± 0.15	50,000	2.4025	26220	1.7196×10^{-12}	1.6862×10^{-12}			
5		22'.00'	Dry	5	1114.7	± 0.2	50,000	2.4025	26220	4.389×10^{-12}	4.209 "			162.1
6	11.33	31'.15" 0.093		6	100.5	± 0.6	100,000	3.105	33900	1.2465×10^{-12}	7.316 "			24.1.12
7		0.221		5	173	± 0.3	100,000	3.105	33900	2.144×10^{-12}	12.22			312
8	15.30	0.222		7	178	± 0.1	100,000	3.105	33900	2.08×10^{-12}				537.2
9		0.300		7	189	± 0.9	100,000	3.105	33900	2.342×10^{-12}				521.1
10		0.504		6	109	± 0.5	200,000	1	205,250	2.654 "				586.8
11		1.02		3	112	± 0.6	200,000	1	205,250	2.962 "				
12		2.005		4	112.5	± 2.6	200,000	1	205,250	3.441 "				

No. of Obs.	Time	Galvo.	Amperes	No. of Throws	Mean Throw	Probable error	Res. in Galvo at	$\frac{G+S}{S}$	Res. of Galvo at	φ	L	H	μ
1	10.22	3'.45.5'		7	28.8	±0.3	0	1	5250	1.52×10^{-12}			
2	10.42	6'.5'		7	50.6	± 0.5	0	1	5250	2.66			
3		13'.15'		8	119.6	± 0.5	0	1	"	4.392			
4		16'.30'		7	154	± 0.8	0	1	"	8.010			
5		22.00		6	220.2	± 0.9	0	1	"	1.360×10^{-12}			
6		0.093 31'.15"		7	62.9	± 0.5	0	1	"	4.091×10^{-12}			
7		0.221		7	114.54	± 0.8	50,000	1	55,250	9.456			
8		0.222		6	138.8	± 0.25	"	1	"				
9		0.300		7	128.3	± 0.5	"	1	"				
10		0.504		6	132	± 0.4	100,000	1	105,250				
11		1.02		4	105	± 1.7	200,000	1	205,250	2.161			
12		2.006		4	134.3	± 1.3	200,000	1	205,250	2.764			

25.2
15.5
9.6 × .00003 = .00288 = 1.00288

3750 ÷ 2 = 3725

3725 + 57 = 3782

$\frac{3782 \times 46.1058}{3725}$ = 46.8113 × 1/1 + 2.0 × 0.0038 = 1.0/1.0076 = 46.4580

$\frac{3725 + 45}{3725}$ × 46.1058 = 46.6627 × 1/1.0076 = 46.3107

26.4 − 19 = 7.4 × 0.03 = 0.222 × 0.467 = 0.1037

Final Determination of a Standard Resistance Coil of Copper for Bergmann & Co.

Both coils soldered and enclosed. Insulation o.k. Standing in water side by side at temp. of 23.1° C by our thermometer #1.

Bridge at 25.2° C., and 46 ω in this = 45.9734 Equal ω standard @ 25.2
= 45.9734 × 1.00288 = 46.1058 ω at temp.

#1 coil 57 ω added to its side. = 46.8113 @ 23.1° C. = 46.4580 ω @ 21.1° C

#2 coil 45 ω - - - - = 46.6627 @ 23.1° C = 46.311 ω @ 21.1° C.

By Bridge

# 1	46.795 − 0.088	= 46.707	@ 26.4° C T.B	= 46.8107 ω	@ 23.1 = 46.4576
# 2	46.550 − 0.088	= 46.462	@ 26.4° C.	= 46.5657 ω	@ 23.1 = 46.2104

Some accident has apparently happened to #2.

On the conductors required to give Incandescent light to Mr Ewell's house.

The feeder to the catch box has a res. of 0.128 ω on each side and those to Archibalds' 0.104 ω making a total of 0.232 ω on each outside conductor.

As the load in winter is usually 80 amperes on each side there must be 10 volts drop at the catch box, and perhaps 12.5 volts drop in all to the house.

If there are 50 lights on Mr Ewell's house at full load = 11 amperes at full load, the drop being say 9 volts = 0.82 ω and for 4000 feet = 0.000205 ω per ft. #6 wire has actually 0.00025 ω and 4000 feet = 8.0 ω ∴ 11 volts drop at full load. This wire is 0.125 lbs per foot × 12000 feet = 1500 lbs. @ 0.30 = $450

80 main at usual price of $0.752 per foot would cost about $3000.

Calibration of Thermometers used as Standards.

On the 3rd Apr. 1890. Observations were taken with three normal thermometers having their bulbs and stems up to zero in washed and broken melting ice.

Chemical Room Standard indicated	−0.4° C.
Our standard #1	+ 0.2
- - #2	+ 0.2

On the 10th Apr. Observations in an apparatus for generating free steam showed :-

Chemical Room Standard	+ 99.35
Our Standard #1 (in steam 440°)	+ 99.0
- - #2 (- - - 50°)	+ 99.2

Barometer at time 75.250
@ 86° F

75.250	
− .046	vibr
75.204	@ 20° C
− .384	
74.810	reduced pressure.

600° F showed 205° F

= 99.6° 0 boiling temp.

Correction to Chemical room standard	+ 0.25
- - Our Standard #1	+ 0.6
- - - - #2	+ 0.4

Table of corrections for our Std #1 is given in Book 1 page 137.

The capillary mercury column was tapped with the finger before all observations in this book.

Res: of Astatic Diff. galv. adj differentially to be permanently mounted on afool side to balance in multiple arc.

7311 = both coils
2 leads
7309 ÷ 2 = 3654.5 ω each coil. Before heat. T.B. 20.8°C

7329 = both coil after heat T.B. 21.8°C
of 1°C temp. extn.
7338
2 leads
7336 ÷ 2 = 3668 ω each coil.

1 div: of scale represents change of about 1ω in balancing resistance.

Res: of H.R.D.S. Diff. galv: adj: differentially to balance in multiple arc.

5421 both coils T.B. 20.8°C
2 leads
5419 ÷ 2 = 2709.5 ω each coil

1 div: of scale represents change of about 3ω in balancing resistance.

Temp: of Oil bath at time of reading capillary tube (after opening same) (292.75K) 19.75°C by #1 standard thermometer. No hysteresis of mercury in effect.

Barometer reading at time of test 76.140
.044 Index error
76.184 @ 23.3°C.

23.3 × 0.00017 = 0.03961
× 76.184 =
.302
75.882 @ 0°C

reading at culminating observation 76.210
.044
24.3 × 0.00017 = 0.0413
× 76.254 =
76.254 @ 24.3
0.375
75.939 @ 0°C.

Corrections same as those facing page 24. 1 KHO cell working through 50ω platinoid standard res: of about 1ω.
Astatic Diff. galv. comparing platinoid res: with coil in air thermometer.
Dead beat " " copper bell coils.
Bridge checking: 0.01ω represented by 3 div. ie KHO cells working.

3pt + K = 0.0115 see preceding cases.

No. of Obs.	Coeff. for Temp.	N	√N	Wt	Wt/N	Wt/N Coeff	General Mean	r	r.m	r²	r³	r⁴
2	0.4037	10	3.16	3	9.48	3.2280		0.0022	4.34 × 10⁻⁴	48.89 × 10⁻⁶	0.1096 × 10⁻⁶	0.0126
3	0.3883	22.4	4.73	3	14.19	5.509		0.0147	7.29	2.55		÷ √5.09
4	0.3902	31.1	5.54	3	16.62	6.533		0.0148	21.46	—	0.159 × 7.99 × 10⁻⁶	= ÷ 23.4
5	0.4076	47.2	6.87	2	13.74	5.600		0.0037	2.96	39.71	= 1.26 × 10⁻⁶	= 126 × 10⁻⁶ / 23.4
6	0.4066	60.0	7.75	3	15.50	6.302		0.0087	0.40	7.54		
7	0.4085	73.1	8.55	4	17.10	6.985		0.0026	2.76	115.60	0.0126	= 5.42 × 10⁻⁶
8	0.4063	84.9	9.21	3	27.63	11.230		0.0004	0.16	4.42		
9	0.4055	95.2	9.91	4	38.64	16.075		0.0004	.16	6.34		
10	0.4062	111.6	10.56	4	42.24	17.160	0.40594	0.0060	0.09	0.54		
11	0.4058	123.2	11.10	1	11.10	4.504		0.0001	.01	0.11		
12	0.4081	135.2	11.63	3	34.89	14.240		0.0022	4.84	168.80		
13	0.4057	148.5	12.20	4	48.80	19.950		0.0028	7.84	382.70		
14	0.4110	161.9	12.72	4	50.88	20.915		0.0061	24.01	1323.00		
15	0.4094	176.2	13.28	5	66.40	27.120		0.0025	6.25	415.10		
16	0.4062	189.2	13.21	3	39.63	14.850		0.0023	0.09	3.30		
17	0.3999	115.5	10.75	4	42.00	16.795		0.0060	36.00	1512.00		
18	0.3995	103.8	10.19	2	20.38	8.141		0.0064	40.96	834.80		
19	0.4010	88.2	9.39	4	37.56	15.060		0.0049	24.01	961.80		
20	0.4017	72.2	8.50	4	34.00	13.660		0.0042	17.64	594.79		
2					579.66	236.790		0.0425	266.67	9364.66		
					3.51	3.15		0.0022				
					31.71	12.345						
					547.97	222.445						

Experiments on the Temperature Coefficient of Copper.

Sunday 30.II.90
This series was practically a repetition of that recorded on page 24, with the addition however of a somewhat higher limiting temperature.

No. of Obs.	Time	Temp. of Room Bridge	Obsd. res. of a ch.	Same with lead deducted 0.350	Obsd. res. of box.	Same with lead deducted 0.321	Obsd. res. of a ch. 0.2.24	Same with lead deducted 0.2.24	Ratio of Change	Barometer Index. Pressure in In.	Barometer Reading	Ratio of Temp.	Temp. of by Coil
1	20.40	20.5	21.7	10.300	9.930	10.290	9.969	20.190	19.866 / 2.79 gms 0.023		20.0	1.0072	11.918
2	.43												14.288
3	.46												17.672
4	.50												20.690
5	.54												24.060
6	21.05	20.6	21.9								10.0	1.0074	27.212
7	.08												30.644
8	.15												33.662
9	.21	21.9											37.044
10	.23												40.042
11	.33										8.0	1.0093	43.644
12	.37												46.492
13	.42	20.6											49.922
14	.46												53.270
15	.55												56.930
16	22.05		22.1					34.520	34.896	1.7211	8.0	1.0093	59.020
17	.09												41.222
18	.17	20.9									11.0	1.0055	38.460
19	.22												34.468
20	.30	20.5	22.2										30.374
21													12.752

No. of Obs.	Coeff. for Temp.	Corrected mean of Temp. 0°C	Coeff.	1/(1+αθ)	Corrected Normal abs. temp	Corrected abs. temp at obs.	Temp. of by mean thermometer	Ratio of T by mean thermometer	Ratio adopted for balance	Ratio in Galvo. calc.	Ratio in Galvo. coil	Ratio	Ratio of resistance	Coeff. per °C. mean
1	1.0002986				292.75	292.5	19.8		1.017	5866.5	3654.5	0.6229		
2	1.0002986	0.0023 / 5.562	1.0338	0.000289	292.86	302.8	29.8	10.0	1600 (1)	5255	3655	0.69552	1.0407	0.4037
3	1.0002986	0.0023 / 5.737	1.07568	1.000570	293.00	315.2	42.2	22.4	1375 (1)	5030	3655	0.72664	1.0584	0.3883
4	1.0003003	0.0023 / 6.746	1.11537	1.001337	293.13	326.9	53.9	34.1	1170 (1)	4825	3655	0.75751	1.13097	0.3902
5	1.0003019	0.0023 / 12.085	1.15941	1.001833	293.28	346.0	67.0	47.2	930 (1)	4585	3655	0.79715	1.19247	0.4076
6	1.0003035	0.0023 / 15.347	1.20243	1.002216	293.43	352.8	79.8	60.0	740 (1)	4395	3655	0.83163	1.24396	0.4066
7	1.0003051	0.0023 / 18.466	1.24526	1.002523	293.58	365.9	92.9	73.1	555 (1)	4210	3655	0.86817	1.29862	0.4085
8	1.0003067	0.0023 / 21.898	1.28935	1.002788	293.71	377.7	104.7	84.9	410 (1)	4066	3656	0.89915	1.34449	0.4063
9	1.0003084	0.0023 / 25.084	1.33044	1.003000	293.86	391.0	118.0	98.2	255 (1)	3912	3657	0.93481	1.39831	0.4055
10	1.0003100	0.0023 / 28.157	1.37562	1.003220	294.00	404.4	131.4	111.6	107 (1)	3765	3658	0.97158	1.45331	0.4062
11	1.0003132	0.0023 / 31.347	1.41415	1.003462	294.114	416.0	143.0	123.2	-10 (1)	3669	3659	1.00273	1.14999	0.4058
12	1.0003165	0.0023 / 34.485	1.45461	1.003723	294.27	428.0	155.0	135.2	-137 (1)	3797	3660	1.03743	1.55181	0.4081
13	1.0003218	0.0023 / 37.891	1.49964	1.003767	294.43	441.6	168.6	148.8	-275 (1)	3936	3661	1.07512	1.60818	0.4057
14	1.0003242	0.0023 / 41.318	1.54470	1.004322	294.58	454.7	181.7	161.9	-415 (1)	4077	3662	1.11333	1.66533	0.4110
15	1.0003317	0.0023 / 44.883	1.59178	1.004605	294.74	469.2	196.2	176.4	-550 (1)	4213	3663	1.15015	1.72046	0.4094
16	1.0003317	0.0023 / 47.971	1.63105	1.005762	294.844	484.0	169.0	149.2	-270 (1)	3931	3664	1.07369	1.60605	0.4062
17	1.0003317	0.0023 / 24.493	1.28818	1.004644	294.11	401.3	135.3	115.5	+ 85 (1)	3780	3665	0.97733	1.46191	0.3999
18	1.0003317	0.0023 / 26.436	1.34939	1.004217	293.93	396.6	123.6	103.8	210 (1)	3876	3666	0.94582	1.41477	0.3995
19	1.0003317	0.0023 / 30.445	1.42710	1.003416	293.75	381.0	108.0	88.2	385 (1)	4052	3667	0.90498	1.35368	0.4010
20	1.0003317	0.0023 / 34.35	1.24616	1.002796	293.57	365.0	92.0	72.2	585 (1)	4258	3668	0.86245	1.29006	0.4017
						767.1	221.1	188.9						
							546.0	396.0						
							767.1	221.1						

Red figures consist of correction of Barometer.

Deposits

	Before	After	Loss
Weight of matte	19275	18190	1085
Weight of anode copper plate	1115	479	636
Weight - cathode -	331	936	-605

The quantity of copper dissolved by 1 amp. sec = 0·03279 gms
" " " hr = 1·181 "

$$636 \div 1.181 = 538.5 \text{ amp. hrs.}$$

$$1085 \div 538.5 = 2.015 \text{ gms. per amp. hr.}$$
$$= 2{,}162 \text{ amp. hrs. per lb.}$$

640,000 amp hrs. dissolve 1 lbs (200000) of matte.
640,000 ¢ watt - - - - - - - - - at counter cost ¢
640¢ ribbon - - - - -
640¢ × 0·776 c - - - - -
= 4·97 ¢ $

The res. of the bath is 0·22ω = 0·15ω per sq. ft
120 d. kwt: hrs mechanical power needed per hr
93·1 d c.
0·93 d $ per hr.

At 24 hours a day the number of sq. feet of matte per hr daily
$= \frac{26{,}600}{d}$

Experiments on Electro-deposition of Matte.

The same large earthenware bath was used as in the experiment recorded on page 20, but the porous division was replaced by a towel fabric of asbestos supported by soft rubber matting, on each side. The matte plate was 10.7" (27.18) × 10.7" (27.18) × 2.25" (5.715). Its total volume was thus 4,232,230 ... + its weight was 6143 g (18230). Its sp. gr. was therefore 2.316

The salt water employed was a filtered solution of density 1.16 @ 18° C. The matte plate was immersed to a depth of 9.4" (38.2) and the surface exposed on one face to the liquid would thus be 9.4 × 10.7 = 100.6 sq. in: (649 □") = 0.7 sq. foot.

A large copper voltameter was joined up in circuit with the bath. The plates were 10.5" (42.6) × 8.25" (33.5) (immersed) in aqueous solution of $CuSO_4$. thus exposing 1427 sq. cms on one face. Density of solution 1.040 at 18° C.

By a series of measurements similar to those on page 20 the counter e.m.f. of polarisation at starting was 1.30 volts and the resistance 0.22 ω; or a res: of 0.15ω per sq. foot. The resistance of the fluid per sq. foot was found as follows:— Two matte plates each exposing (approximately) 1 sq. ft on each face immersed in bath parallel.

Res: of leads 0.03 ω.			bare lead
- between plates separated by	0.5" (1.26)	0.07ω	= 0.04
- - - - -	1" (2.5)	"	"
- - - - -	2" (5.0)	0.08ω	0.05
- - - - -	2.5" (6.3)	0.09	0.06

2" distance increased res. by 0.02ω or about 0.01ω per inch of distance. The res. per sq. foot will therefore be (0.04 + 0.01 s)ω where s is the distance apart in inches. The distance between the matte and carbon is 4", and the res: should be 0.08 = 0.11 + the res: of the carbon plate which should be negligible. The res: of the porous diaphragm is thus 0.11ω or 0.08ω per sq. foot.

The following results were obtained after the test had been running for over 24 hours and are therefore probably reliable.

No. of Obs.	Before scraping: Bloch	Current	P.D.	Counter emf	P.D. corr. bath (P.D.−c.e.m.f.)	$ per hr TENT	$ per hr	After scraping: Bloch	Current	P.D.	Counter emf	P.D. corr. bath	$ per hr Comp.	$ per hr Comp.
1	1·82	9·19	3·7	1·68	2·02	1·7 volts	12·10	1·86	9·39	3·6	2·07	1·53	1·57 volts	12·11
2	1·66	8·38	3·55	1·71	1·84		11·16	1·60	8·05	3·35	1·78	1·57		11·16
3	1·48	7·47	3·40	1·76	1·64	$9·50	9·80	1·38	6·97	3·10	1·88	1·57	$7·85	9·67
4	1·24	6·26	3·1	1·72	1·38		8·37	1·13	5·67	2·80	1·25	1·55		8·10
5	0·95	4·80	2·8	1·74	1·06		6·51	0·795	4·00	2·45	0·88	1·57		5·93
6	0·64	3·23	2·4	1·69	0·71		4·38	0·444	2·22	2·0	0·49	1·51		3·29
7	0·44	2·22	2·15	1·66	0·49		2·98							
8	0·235	1·18	1·85	1·59	0·26		1·58							
9	0·140	0·71	1·72	1·56	0·16		0·93							

Permeability of certain samples of Ferro-aluminium Castings from Schenectady

Small anchor ring of Mitis iron

A	B	C	D	E	F	G	Mean DEFG	Mean area of X section	Weight in air	Weight in water	Volume by weight	Volume by form	Sp. g.
18.2	16.05	16.05	1.121	1.123	1.12	1.125	1.122	1.019	407.9	352.9	55	54.8	7.4
	Turns on 1st layer	Turns on 2nd layer	Turns on 3rd layer	Turns on 4th layer	Total turns.	Total primary turns	Total secondary turns	Mean circumf. of ring	Turns of primary per cm.	1.257 × Turns of primary per cm.			
	335	328	274	231	1168	505	663	53.80	9.39	11.81			
	Time	Source of E.M.F.	Bonds.	EMF at temp.	a × 10⁷	No. of throws	Mean throw	τ (throw)	Value of 1 div.	Mean value of 1 div.	a 2πk/63		
	15.00	2 Cells 22C	0.408†	2.860	1.167	13	103.15	± 0.2	8.838 / 1.399×10⁻⁴	1.11×10⁻⁴ / 8.80			
	17.00	2 . . 23C	0.408†	2.858	1.166	5	102.5	± 0.1	8.790 / 2.0975	8.370×10⁻⁴	1.261		
No. of Obs.	Time	Galvo Defln	Amperes	No. of throws	Mean Throw	τ (throw)	Res. in cct. with Galvo	Total res. in Galvo cct.	a 7526	φ	B	μ	H
1	14.02	6.10′	0.0814	5	49.2	± 0.6	0	52.50	3.266×10⁻⁴	1.714×10⁻⁴	168	175	4.96
2	14.15	6.50′	0.0903	5	54.2	± 0.4	0	-	3.598	1.889	185.4	173.8	1.047
3	·20	8.0	0.1059	5	67.9	± 0.9	0	-	4.507	2.366	224.3	183.3	1.251
4	·36	9.0	0.1194	6	82.4	± 0.6	0	-	5.470	2.871	281.8	199.5	1.410
5	·45	12.05′	0.1614	6	190.1	± 1.3	0	-	12.62	6.626	658.3	314.2	2.096
6	·51	14.45′	0.1985	7	147.9	± 0.5	25000	25250	3.179	1.688	914.0	402.8	2.268
7	15.00	22.0′	0.3047	7	141.8	± 1.0	"	-	9.41	2.847	2794.0	7764	3.598
8	·10	{55.30′ / 8.222}	{1.097 / 1.131}	5	111.3	± 0.2	100000	105250	7.388	3.776	8613.	657.6	13.10
9	·21	0.398	2.010	5	136.9	± 0.05	"	"	9.087	3.544	9386.	395.2	23.75
10	..	0.698	3.526	7	78.4	± 0.3	200,000	205,250	5.204	1.068	10,480	251.7	41.64
11		1.050	5.456	7	83.4	± 0.1	-	-	5.536	1.136	11,150	162.2	68.33
12		1.520	7.678	6	88.0	± 0.25	-	-	5.841	1.199	11,770	123.2	90.67
13		2.914	14.350	5	95.5	± 0.1	-	-	6.339	1.301	12,770	75.37	169.4
No. of Obs.	Galvo Defln	Tam.	Amperes for tam 1.	Res. in cct of tam	Total res. corrected		Corrected φ	Corrected B	corrected μ	H	ρ		
1	6.10′	0.1080	0.754	4l + 110ω	1300ω		216.	212	221	0.96	4525		
2	6.50′	0.1198		4l —			238	234	219	1.067	4.566		
3	8.0′	0.1405		3l + 110ω			299	289	231	1.251	[illegible]		
4	9.0	0.1584		3l —			362	335	252	1.410	3.[illegible]		
5	12.05	0.2141		2l + 110ω			836	820	420	1.996	2.316		
6	14.45′	0.2633		2l —			1213	1190	508	2.344	1.969		
7	22.0′	0.4040		1l + 110ω			3591	3524	979	3.598	1.021		
8	55.30′	0.4550		110ω			10890	10560	829	13.10	1.206		
							12060	11840	498	23.75	2.004		
							13470	13220	317	41.64	3.155		
							14320	14070	205	68.43	4.678		
							15120	14850	155	90.67	6.452		
							16140	16110	95	169.4	8.53		

On the Permeability of Mitis Iron from Schenectady
Correction of observations taken on page 22.

A	B	C	D	E	F	G	Mean DEFG	Wt in air	Wt in water	Vol. by B.&S.	Vol. by formula	Sp. G.
18.2	16.05	16.05	1.12	1.123	1.12	1.125	1.122	407	352	55	56.53	7.44
	No. of turns in 1st layer	Turns in 2nd layer	Turns in 3rd layer	Turns in 4th layer	Total for turns	Total sec turns	Mean circumference	Mean turns per foot	Area of x section	1.257 × A × turns per foot		
	335	234	250	234	4824	569	53.80	8.995	1.019	9.166		
	EMF	Log.	$a \times 10^7$	No. of Obs.	Mean Turns	σ (Turns)	Mean per div.	Mean a per div.	$\frac{a}{1838}$			
	1.431	1.000	1.431	6 10	173.7 176.5	± 0.16 ± 0.6		8.166×10^{-10}	7.175×10^{-10}			
No. of Obs.	Time	Galv. Defl.	Amperes	No. of Turns	Mean Turns	σ dim	Res. of Galv. ck	$\frac{G \times S}{(S+G) \times 1000}$	Influence Turns	$\frac{a}{1838}$	φ	
1	14.15	14.07	0.190	5	29.7	± 0.7	30,200	5.21	154.7	1.110×10^{-10}	2.242×10^{4}	
2	.27	{26.15 8.061}	{0.372 0.105}	7	57.0	± 0.6	-	-	297	2.131	4.304	
3	.55	0.120	0.606	6	77.0	± 0.4	-	-	401.	2.878	5.813	
4	15.09	0.214	1.080	4	92.5	± 0.25	-	-	482	3.459	6.986	
5	.17	0.302	1.526	7	44.1	± 0.5	45,200	-	229.8	1.649	7.454	
6	.30	0.510	2.576	6	48.8	± 0.5	-	-	254.3	1.825	8.248	
7	.38	0.760	3.84	4	51.1	± 0.4	-	-	266.3	1.911	8.638	
8	.45	1.025	5.178	2	55.0	± 1.6	-	-	286.6	2.056	9.292	
9	.45			3	120.0	± 2.6	24,200	-	625.2	4.487	9.886	
10	.48	1.615	8.16	2	128.5	± 1.2	-	-	669.5	4.805	9.704	
11	.56	2.390	12.07	2	135.0	± 1.7	-	-	703.4	5.048	10.200	
12	16.00	0.210	1.061	3	92.7	± 0.5	-	-	483.0	3.466	7.000	
No. of Obs.	$\varphi \times 10^3$	$\frac{\varphi}{\mu} \times 10^3$	6H	Amp	H	μ						
1	2.242	2.200	10.43	0.190	1.74	1265	0.7905					
2	4.304	4.225	18.427	0.340	3.116	1356	0.7375					
3	5.813	5.706	33.22	0.606	5.554	1027	0.9737					
4	6.986	6.858	59.21	1.080	9.898	693	1.443					
5	7.454	7.317	83.66	1.526	13.99	523	1.912					
6	8.248	8.096	141.2	2.576	23.61	343	2.915					
7	8.638	8.478	210.5	3.840	35.20	241	4.149					
8	9.292	9.122	283.9	5.178	47.46	192	5.209					
9	9.886	8.898				187.5	7.85					
10	9.704	9.526	447.4	8.160	74.80	127.3	7.85					
11	10.200	10.010	661.8	12.07	110.6	91.3	10.9					
12	7.000	6.870	58.17	1.061	9.72	707						

Permeability of samples of cast iron from Schneider & Co.

All primaries in series and secondaries connected in turns to galvo.

No. of Ring	A	B	C	D	E	F	G	Means DEFG	Wt. in air.	Wt. in water	Vol. by H_2O	Vol. by form	Sp. gr.
1	25.39	19.05	19.05	3.15	3.2	3.15	3.25	3.19	3983?	3459	524?	556	7.16
2	25.45	18.93		3.25	3.15	3.5	3.20	3.26	4004	3428.6	575.4	581.8	6.96
3	25.10	18.95	3.3 3.3	3.1	3.2 3.25	3.15	3.25 3.05	3.20	3877	3336	541	556.3	6.97
4	25.10	19.0	19.0	3.2 3.1	3.2	3.15	3.2	3.17	3884	3331	553	546.8	7.13
5	25.20	18.8	18.95	3.25 3.15	3.1	3.25	3.25	3.20	4025.5?	3402	623.5?	558.7	7.23

No. of turns 1st layer	Turns on 2nd layer	Turns on 3rd layer	Total turns	Total primary turns	Total Sec. turns	Mean diam.	Primary turns per cm.	Area of X Section	1.257 X pr. turns per cm.	No. of rings	Bamboo insul. by coating % at.	Bamboo insul. % of Wt. by weight
383	166	163	712	329	383	69.660	4.722	7.98	5.936	1	Ord. Bamboo	0.06%
393	183	174	750	357	393	69.705	5.121	8.347	6.436	2	" "	0.06%
386	175	158	719	333	386	69.200	4.812	8.040	6.048	3	1:38	0.06%
381	175	161	717	336	381	69.280	4.850	7.892	6.096	4	1:38	0.06%
380	183	163	726	346	380	69.230	4.998	8.040	6.281	5	~~1:38~~	~~0.07%~~

No. of turns	Source of EMF	Resist.	EMF at temp	a	No. of Rings	Mean Rad.	σ_m (calc)	Mean a per cm	a / 2πr			
1	2 dech. cells @ 21°C	0.409 Ω	2.663×10^{-8}	1.171×10^{-7}	7	103.3	± 0.1	1.134×10^{-8}	1.48×10^{-10}			
2		$\times 10^{-3}$						~~1.443~~	1.443			
3									1.469			
4									1.489			
5									1.492			

No. of turns	Resist. of primary	Resist. of secondary.	Insulation between pr. & sec. by bamboo.
1	0.145 Ω	0.61 Ω	∞
2	0.155 Ω	0.63 Ω	∞
3	0.145 Ω	0.62 Ω	∞
4	0.150 Ω	0.60 Ω	∞
5	0.155 Ω	0.615 Ω	∞

Permeability Measurements of five samples of iron from Schemeldody

No. of Obs.	Force	Galvo Defl.	Time	[illegible]	D 3.28 No. of Hours	Mean Hour	r dist.	Rev. in est. coil. g	Rev. of G. est.	1.48 φ	L	H	μ	3/05 No. of Hours	Mean Hour	r dist.	1.483 φ	L	H	μ
1	8·53	6·40'	0·11699	0·0881	6	26·3	±0·25	0	5250	2.043×10^{10}	256	0·523	49	6	43·2	± 0·1	3.27×10^{10}	39·2	0·567	69
2	9·16	13·50'	0·24424	0·1857	6	58·2	± 0·24	0	"	4·522	56·7	1·103	51	6	94·8	± 0·7	7·184 "	86·1	1·195	72
3	9·50	25·15'	0·53732	0·4051	6	71·0	±0·8	50000	10250	1.077×10^{10}	135	2·405	56·1	7	122·4	± 0·3	1.810×10^{10}	217	2·608	83
4	10·18	54·30'	1·4019 0·222	1·057 1·121	6	150·7	± 0·8	25000	30,250	6·746	846	6·375 6·652	135 127	6	170·2	± 0·5	7·428	890	6·902 7·214	131 123
5	10·37		0·409	2·066	6	143·4	± 0·4	100,000	105,250	2.233×10^{10}	2800	12·27	228	6	153·2	± 0·6	2.325×10^{10}	2790	13·3	210
6	11·00		0·713	3·612	7	120·1	± 0·2	200,000	205,250	3·649	4570	21·45	213	7	127·2	± 0·9	3·766	4510	23·25	194
7	11·19		1·000	5·05	6	97·5	± 0·1	300,000	305,250	4·406	5520	29·98	184	6	103·2	± 0·2	4·546	5450	32·51	168
8	11·37		2·084	10·12	6	131·2	± 0·4	300,000	"	5·927	7430	60·07	124	6	137·3	± 0·2	6·049	7250	65·114	111
9	11·40		2·000	20·21	2	166·3	± 0·3	300,000	-	7·512	9414	120·0	78·5	2	171·5	± 0·8	7·554	9050	130·1	69·6

No. of Obs.	D 3.28 No. of Hours	Mean Hour	r	H	1.483 φ	L	μ	D 3.28 No. of Hours	Mean Hour	r	1.483 φ	L	H	μ	3/05 No. of Hours	Mean Hour	1.483 φ	L	H	μ
1	6	43·3	±0·2	0·53	3.348×10^{10}	41·6	78·	6	43·3	±0·1	3.38×10^{10}	42·8	0·537	79·7	6	37·5±0·2	2.94×10^{10}	36·6	0·55	66·5
2	6	95·1	±0·2	1·123	7·336	91·2	81·	6	95·0	± 0·2	7·425	94·1	1·132	83	6	82·5±3	6·49	80·7	0·66	69·2
3	6	122·6	± 0·3	2·45	1.886×10^{10}	230·	94·	6	121·7	± 0·2	1.857×10^{10}	235·3	2·47	95·	6	105·3 ±0·6	1.611×10^{10}	200·4	2·54	78·8
4	6	169·3	± 0·4	6·39 7·8	7·524	936	147 138	6	171·6	± 0·2	7·716	978	6·44 ·83	152 143	6	135·7 ±0·2	6·128	762	6·636 7·040	115 108
5	7	147·7	± 0·1	12·5	2.283×10^{10}	2840	227	6	147·2	± 0·1	2.307×10^{10}	2920	12·6	232	6	132·6±0·2	2·083	2590	12·97	200
6	7	122·7	± 0·1	21·85	3699	4600	211	7	121·6	± 0·2	3·716	4710	22·02	214	7	114·7 ± 0·1	3·513	4370	22·69	193
7	6	99·3	± 0·2	30·55	4·454	5540	181	6	98·3	± 0·1	4·469	5660	30·79	184	6	93·5 ± 0·2	4·273	5315	31·72	168
8	6	131·5	± 0·3	61·2	5·896	7334	120	6	130·2	± 0·8	5·918	7500	61·68	122	6	127·8 ± 0·1	5·821	7241	63·55	114
9	2	163·0	± 0·0	122·2	7·310	9090	74·	2	162·25	± 0·1	7·374	9345	123·2	76	2	160·5±0·4	7·310	9092	127·0	[illegible]

A sample of this rayligist iron wire (0.020") was weighed as follows:

in air	10·475 g.
" water	8·700
loss.	1·775

sp. g. 5·90

Another sample of the same wire very slightly roughed

in air	10·700
" water	9·270
	1·430

sp. g. 7·12.

In the cylindrical form the density might be

$0.7854 \times 5.9 = 3.927$

as a limit perhaps 4·0 under pressure

This coil had a sp. g. of about 3·37 so that, the space actually occupied by wire was $\frac{3.37}{5.9}$ of the total space.

On scraping off the oxide from the wire the diameter of the latter was found to be reduced to 0·18 or in ratio $\frac{324}{400}$, 0·81

Finally, the space occupied by iron would only be 0·7854 of the space occupied by compressed wire, so that the iron in the cross-section of this wire only occupied

$\frac{3.37}{5.9} \times 0.81 \times 0.7854 = 0.3635$ total space. $= \frac{1}{2.75}$

Permeability of Sample Castings of Iron from Schneckady, and our Rayligist wire.

Description	A	B	C	D	E	F	G	Mean DEFG	Wt in air	Wt in water	Wt by H_2O	Wt by Form	Sp. g.
Wire (rayligist)	23·57 23·3 23·1	18·4 (22·2) 17·5 (18·9) 17·97	2·55	2·75	2·6	2·7	2·75	2·69	1247	-	-	370	3·37
Metis	18·2	16·05	16·05	1·12	1·123	1·12	1·125	1·122	409·9	352·9	55	54·8	7·4

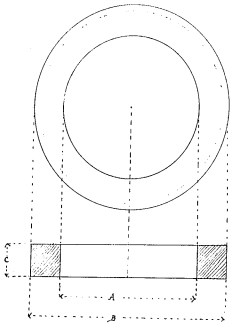
Description	Turns 1st layer	Turns 2nd layer	Turns 3rd layer	Turns 4th layer	Total turns	Total Arr. turns	Total Section	Mean diac.	Turns of per cm	1·267 × Turns per cm	Mean area of X section	Res. of Arr.	Res. of Sec.
Wire	379	170	162	–	701	332	379	65·08	5·10	7·1444	5·683	0·11 ω	0·51 ω
Metis	335	328	322	303	1288	953	335	53·8	17·71	22·26	1·019	0·89 ω	0·22 ω

Description	Source of EMF	Temp	EMF @ temp	Coeff. ρ	a ×10⁻⁷	No. of turns	Mean turns	t (Wire) (Metis)	a per div.	a (Wire) (Metis)	
Wire	2 Ba.	20°C.	2·865	0·410	1·175	6	103	±0·1	×10⁻⁹ 1·1425	1·505×10⁻⁷ 1·702×10⁻⁷	
Metis											

No. of Obs.	Time	Galvo.	Tangent	Ampère	No. of turns	Mean turns	t (Wire) (Metis)	Res. of G. ckt.	φ	Z	H	μ	1·505×10⁻⁷ × 4π×10⁻⁷
1	9·06	6°40'	0·1169	0·081	6	23·1	±0·2	5250	192·5	32·014	0·579	55·3	7·90
2	·33	12°	0·2126	0·160	6	45·8	± 0·3	"	361·8	63·67	1·143	55·7	
3	·45	22°	0·4040	0·3047	7	110·2	± 0·8	"	870·4	153·2	2·177	121·3	
4	·57	55°30' 0·217	1·4550	(1·097 / 1·096)	6	127·1	± 1·0	105,250	16670	2938	7·834	37·43	1·5834×10⁻⁷
5	10·12	0·435		2·97	6	170·6	± 0·9	"	27020	4754	15·70	30·38	
6	·29	0·700		3·536	6	96·5	± 0·5	205,250	29810	5245	25·27	20·76	3·089 × 10⁻⁷
7	·40	1·080		5·455	7	108·1	± 1·1	"	33400	5877	38·97	15·68	
8	·.	1·92		9·790	6	114·4	± 0·5	"	35326	6219	69·32	8·97	
9		4·65		23·500	7	120·9	± 0·9	"	37350	6572	167·9	39·13	

No. of Obs.	Ampère	No. of turns	Mean turns	t (Wire) (Metis)	Res. of G. ckt.	φ	Z	H	μ	1·702×10⁻⁷ × 4π×10⁻⁷	ρ	Z for unit × 2·75	
1		6	99·8	±0·4	5250	892	8·756	1·803	485·7	8·936	0·2057	88·	
2		6	79·4	± 0·5	30,250	7090	4020	3·561	1129	51·490	0·4557	175	
3		6	143·3	± 0·3	30,250	7350	7244	6·781	1088	51,490	0·9191	421·1	
4		6	69·7	± 0·2	105,250	12490	12,260	21·42	511	179·15	1·957	5066	
5		6	79·7	± 0·8	"	14,280	14,020	48·90	292	"	3·426	13060	
6		6	85·5	± 0·3	"	15,320	15,040	78·70	195	"	5·128	14420	
7		6	90·7	± 0·3	"	16,250	15,950	121·40	131·4	"	7·60	16160	
8		6	98·2	± 0·2	"	17,600	17,280	215·9	80·0	"	12·5	17100	
9		–	–	–	–					"		18600	

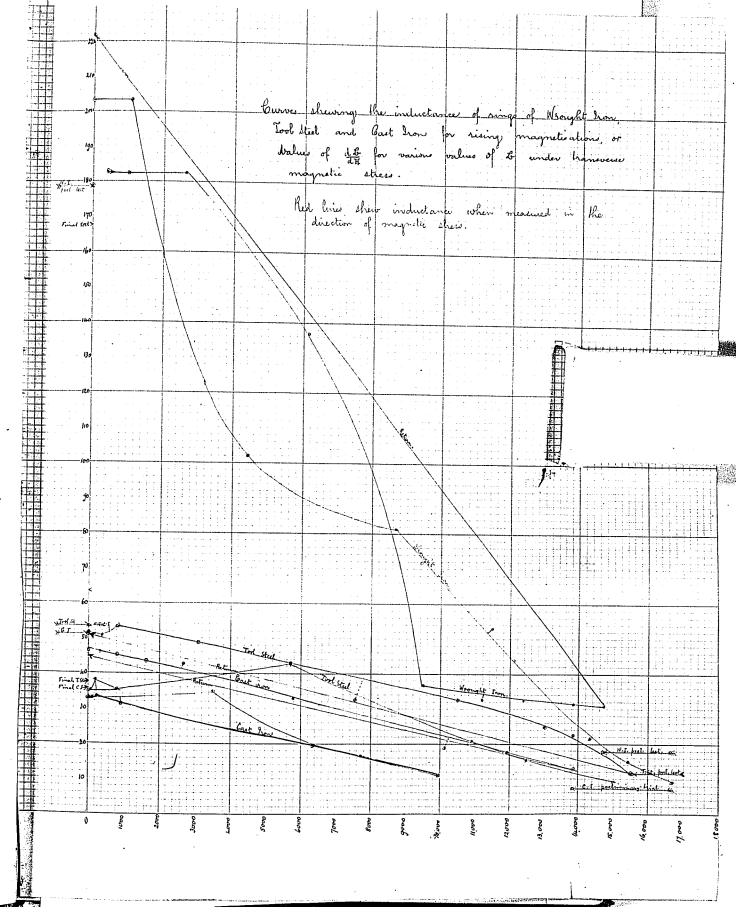
Plan & section of Rings Full Size.



27·3
16·0
8·3 × 0·03 = 0·25 % = 1 + 0·0025

22 × 0·0025 = 0·05 ·4

2·2 = 2·2005 ·4



The inductance of a ring of radii 9.75 and 2.6 with 289 turns and a depth of 1.2 should be

$$2 \times 289 \times 289 \times 1.2 \times \log_e \frac{3.75}{2.6}$$

$$= 2 \times 83{,}520 \times 1.2 \times 0.3667 = 73{,}500 \text{ cms} = 0.735 \text{ Kilomts}$$

the value found being 0.929 .

Experiments on the Permeability of Iron at right angles to imposed magnetisation.

To measure the difference of magnetic permeability in directions coincident with and at right angles to imposed magnetisation in iron took four rings of dimensions shown

No. of Ring	Material	A cms	B cms	C cms	Mean Diam cms	× sectional area Ferron	Vol. by formula c.c.	Weight in air grammes	Weight in Water grammes	Vol. by weight c.c.	Sp. g.
1	Pine wood	5.20	7.42	1.13	6.36	1.198	23.94	10.704	–	–	–
2	Wrought iron	5.22	7.42	1.12	6.32	1.232	24.465	188.915	164.200	24.715	7.6444
3	Best "	5.22	7.42	1.12	6.32	1.232	24.465	172.270	148.050	24.220	7.11
4	Tool Steel	5.22	7.42	1.12	6.32	1.232	24.465	191.310	166.865	24.445	7.826
									m	24.400	

All these rings were wound with one layer of #28 silk-covered copper wire 0.01142" count to 0.018" (0.03361 to 0.04577) over an wrapping of oil paper to keep the wire from the ring. The surfaces of the rings were not polished but were planed true and smooth. The number of turns of this wire was 289 on each ring = $\frac{289 \times 12}{12}$ = 28.8 ft say 28.8 ft with one + slack @ 0.0527 per ft = 2.635 ω. The resistance and weight were

No. of Ring	Material	Weight in Wind	Weight in water	Weight of wire added	Res. of coil	Temp. of Bi coil		Σ(D²−d²) superficial mm.	D²	d²	D²−d²
1	Wood	29.030	10.714	18.296	2.15ω	22.5°C.		28.47	55.056	28.090	26.966
2	W. I.	207.85	188.915	18.935	2.17ω	22.5°C.		21.845	55.056	27.248	27.808
3	B. I.	190.90	172.270	18.630	2.21ω	22.5°C.		21.845	55.056	27.248	27.808
4	T. St.	210.92	191.31	19.61	2.21ω	22.5°C.		21.845	55.056	27.248	27.808

The inductances of these rings was measured when removed from the neighbourhood of magnetised bodies with the following results.

No. of Ring	Ratio of bridge	Res. Ard @ 27.3°C	Res. add @ 4°C.	Capacity for balance	Inductance Henrys	Magnetic Potentiometer	ψ	ψ²	Σψ²	Probable error of mean	τ_m
1 Wood	1000/10	2.196	2.250	0.043 μ	9.675×10^{-5}	0.9285	−0.0390	0.001521	0.003267	0.000102	0.000149
		2.210	2.264	0.0442	9.588		−0.0223	0.000497			
		2.215	2.269	0.0440	9.076		+0.0210	0.000441			
		2.216	2.270	0.0440	9.080		+0.0205	0.000420			
		2.218	2.272	0.0440	9.088		+0.0197	0.000388			1.5%
							1.4142 × 0.0149				
2 Wrought iron	1000/100	2.205	2.259	0.750	1.694×10^{-2}	167.5	−1.9	3.61	29.97	10.11	4.519
		2.200	2.254	0.723	1.630		+2.5	2.25			2.70%
		2.229	2.283	0.730	1.667		+0.5	0.25			
		2.229	2.283	0.742	1.694		−1.9	3.61			
		2.229	2.283	0.740	1.690		−1.5	2.25			
			147	4.97							
			5.00								
			4.97								
3 Best Iron	1000/100	2.262	2.317	0.226	5.236×10^{-2}	53.40	+1.54	1.032	4.588	1.547	0.69
		2.262	2.317	0.230	5.329		+1.11	1.232			1.29%
		2.265	2.320	0.235	5.452		−1.12	1.254			
		2.267	2.322	0.230	5.341		−0.01	1.020			
		2.267	2.322	0.233	5.341		−0.01	0.000			
4 Tool Steel	1000/100	2.256	2.310	0.275	6.355×10^{-2}	53.26	−0.29	0.084	10.944	3.690	1.65
		2.268	2.323	0.260	6.039		+2.97	8.24			2.61%
		2.265	2.320	0.275	6.381		−0.56	0.30			
		2.269	2.324	0.275	6.341		−0.65	0.42			
		2.254	2.309	0.280	6.466		−1.38	1.90			
			63.5	11.89							

Experiments on the permeability of iron in a direction at right angles to imposed magnetisation.

In these inductance ~~experiment~~ measurements, recorded on the last page the resistance of the leads was 0.090ω, and the current would be approximately $\frac{14 \times 0.75}{100 + 3} = \frac{3}{103} = 0.029$ amps, while H would be approximately

$$\frac{289 \times 1.257 \times 0.029}{3.14 \times 6.38} = \frac{10.53}{20.03} = 0.53$$

L in wrought iron would be $\frac{167.5}{0.93} \times 0.53$ i.e. as shown in the next table.

The reason for the small precision of these inductance measurements, particularly in the case of wrought iron was the unsteadiness of the spot, and in fact the slow change of magnetisation of wrought iron for such low values of H, rendered accurate determinations of inductance impossible.

No. of Ring	Inductance Kilometres	μ	H	L						
1	0.9285	1	0.53							
2	167.5	180.4		95.62						
3	53.14	57.5		30.48						
4	63.26	68.14		36.12						

These rings were then placed between the poles of the large electromagnet in successive measurement, one at a time, with their planes at right angles to the magnetic axis. The polar faces are planes 7.14 × 7.3 and thus completely cover the iron in the rings when the latter are placed (concentrically) between them to their magnetic axis. The pole in each measurement were about 1.6 apart (1.4 at the top and 1.8 at the bottom)

To measure the induction passing through the rings in a direction normal to their planes, five turns of silk covered copper wire diam. 0.012" (0.0254) covered to 0.014" (0.035) wound the ring externally and five similar turns internally. The five exterior turns were laged over tapes, in the center of its breadth and in a plane parallel to that of the ring surface. The interior turns were wound over a slightly conical core about 4.85 in mean diam. and about 1 cm thick which when wedged into the ring held the five turns accurately close up to the iron.

The dimensions of these turns are given in the next table.

No. of Ring	Material	No. of turns	Total length of wire	External Diam. mean	Diam. mean	Rings area	Diam. of turns mean	Area.	Length of turns working spec	Area of turns working spec	Diam. of tapes. Tapes
1											
4	Wrought Iron	5	126.7	25.34	8.064	51.07	7.42	43.244	0.322	7.30	7.65
3	Cast	"	122.4	24.48	7.790	47.66	7.42	43.24	0.185	4.42	
2	Cast Iron	"	122.4	24.48	7.790	47.66	7.42	43.24	0.185	4.42	
					Internal	Turns					
											Diam. of wire before covering
4	Tool Steel	5	77.47	15.494	4.931	19.10	5.22	21.40	0.145	2.30	5.0
3	Cast Iron	"	77.46	15.492	4.931	19.10	5.22	21.40	0.145	2.30	4.95
2	Wrot iron	"	77.46	15.492	4.931	19.10	5.22	21.40	0.145	2.30	4.95

Experiments on the permeability of iron in a direction at right angles to imposed magnetisation.

The inductance of these rings was then measured in the same manner as before when the electromagnet was unexcited and when powerfully excited, so as to obtain a rough determination of the limiting effect. The current thro' the magnet coils was either 0 or about 20 amperes.

No. of Ring	Ratio of B.	Res. obtd. μ	Bonds	Current on magnet	Inductance Henries	μ	Res. obtd	Bonds	Current on magnet	Inductance	μ_c	$\frac{\mu_c}{\mu}$	H
2 W.I.	10000/10	4·465	0·4	0	178·6	17·4	4·465	0·04	20 amp	17.86	17.4	10	0·5
3 G.I.	10000/10	4·522	0·113	0	57·1	49·8	4·522	0·016	"	7·236	7·05	7·25	
4 T.St.	10000/10	4·514	0·118	0	53·26	51·9	4·514	0·030	"	13·542	13·2	3·93	
1 Wood	10000/10	4·464	0·023	0	1·027	1	4·464	0·023	–	1·027	1	1·0	

These measurement were next repeated more carefully as follows, viz. including the determination of the induction through the ring and inside it. Corrections are introduced for the winding space, which prevents the five measuring turns from fitting the ring closely. The results give the diminution in μ for H = 0·5 round the ring for any given value of H passing through the ring normal to its plane.

Finally, the exterior and interior 5 turns of exploring wire were removed and the rings wound with two layers of cotton covered wire (see later) 0·017" covered to 0·026" (0·043 to 0·066). The particulars concerning this winding are :—

No. of Ring	Material	Turns on 1st layer (outside)	Turns on 2nd layer (outside)	Total turns	Turns per cm. mean circ.	1·257 × Turns per cm.	Mean inst. diam. over wire	Mean int. diam. over wire	Mean diam. of wire only	Mean diam. of wire only	Mean of ext. + int. diams.	
2	W.I.	101	92	193	9·626	12·10	4·00	8·3	20·05	6·38	6·15	
3	G.I.	101	91	192	9·576	12·04	4·25	8·4	20·05	6·38	6·33	
4	T.St.	113	107	220	10·97	13·785	4·20	8·35	20·05	6·38	6·28	

Under these conditions, the three rings were connected in series and their induction at observed current strengths determined in the usual manner, the secondaries being connected successively to the ballistic galvanometer while the current was reversed in the primary circuit. The inductance by bridge was also determined at each step. The general result gives the measured inductance of the ring for any given value of H along the ring or normal to it.

After these results were obtained the inductance of the ring in air 22nd Apr. 90 with :—

No. of Ring	Material	Ratio of Bridge	T.B.	Temp. of air	Res. obtd	Bafy	Inductance Henries	Original Inductance	
1	Wood	10000/10			2·135 ω	0·048	0·9684	0·9285	
2	W.T.	10000/10			2·29	0·700	148·47	167·5	
3	G.I.	"			2·170	0·159	35·50	53·4	
4	T.St.	–			2·179	0·168	37·60	63·26	

Measurements of Inductances of rings at right angles to Direction of Magnetic action in Multiple Coils.

i Coils all in series @ 25·5°C Mean φ 0·1409 g

Secondary E.M.F.	T sec	EMF at Bordeaux	Q_1 $\times 10^7$	No. of Turns	Mean Turns	r_m	Value of $\frac{r_m}{a}$ =
2.C.C.	25·5°C.	2.5226	0.4079	1·1·67	8	101·9	±0·7	1·145×10⁻³

$\varphi_1 = \frac{52250 \times 10^{10}}{4 \times 2.5 y} = 5{\cdot}08_m \times 10^7 Q$

$\varphi_3 = \frac{t \times 10^7}{10} = 10^7 \times Q_1 r = 5{\cdot}250 \times 10^{10} \times Q_1 \times 10^{-7} = 5{\cdot}25 Q$

$\varphi_2 = \frac{\pi q \times 10^2 \times 10^{-1}}{10}$

Res of Coils 2·375 Ω
" " " 0·1146 Ω
" " " 0·2495 Ω

Coil No.	Deflex. Galv. in C.G.S.	Times	Current in E. magnet.	No. of Turns	Mean Turns	r_m dia.	Res. of Galv. Ckt.	Q	T	φ Eqt. = 1250	Φ
			Coil #1								
1	6·45'	0·11836	0.089	1	3	-	5·250	3·435×10⁻⁷	2·5	31·20	25·3
2	13·45'	0·24447	0.1645	1	3	-	-	3.435		31.2	25·3
3	29·45	0·57¼' 0·09¼ 1·47¼	0·438 0·1455 0·394	1	7	-	-	8·01		72·76	59·1
4		2·198 0·350	1·70 1·16 } 1·48	1	5	-	-	5·725		52·0	42·2
5		0.438 0.130	2·197 2·172 } 1·95	1	57	-	-	65·26		592·0	48·2·0
6		5·73 1·39	3·617 2·382 } 3·51	1	83	-	-	95·04		863·0	70·10
7		1·05 1·10	5·15 2·555 } 5·85	1	90	-	-	103·1		936·0	76·0.0
8		2·35 2·20	14·87 11·31 } 11·59	1	86	-	-	98·47		89·5·0	72·7·0
9		3·68	18·6	2	78	±0	-	89·32		811·0	65·8·0
10		0		-	-						

Coil #3 (Inductive) No. of Turns	Mean Turns	r_m dia	Res. of Galv. ckt.	$\frac{a}{\pi}$	φ	Mean value
2	0	-	5250	0	0	1·12.05
3	2·6	±0·9	"	2.477×10^{-3}	1.667×10^{-3}	
3	6·3	±0·5	"	7·211	3·787	
3	24·8	±0·1	"	30·69	16·11	
3	66·5	±2·2	"	76·15	39·97	
3	76·3	±0·3	"	87·38	45·86	
3	81·7	±0·5	"	93·52	49·11	
3	93	±0·8	"	106·5	55·91	
3	93	±2·4		106·5	55·91	
-	-					

No. of Obs.	Corrected int. φ	Corrected int. Φ	Coil #3 No. of Turns	Mean Turns	r_m dia.	Res. of Galv. ckt.	Q	Φ	Correction for winding φ	Corrected Φ	Φ − φ Tabulation φ	Φ in mm.	Ratio of Radius	Res. dec.	Rad.	Inductance Henrys
1	0	0	2	16·5	±0·4	5250	18·9×10⁻⁷	99·22	0	99·22	99·20	5·54	1000/100	4·5559	0·400	18236
2	17·51	81·8	3	41·7	±0·5	"	47·75	25,070	360	24,710	22·960	1050		4·5554	"	182.16
3	42·43	195·3	3	104·2	±0·5	"	119·3	62,630	877	61,753	57,510	2630	T.B. 27·5°C.	4·5557	-	182.25
4	18,050	8423	3	45·0	±0	30,250	5653	155,900	3728	152,172	136,120	6140		4·560	0·300	136·8
5	44,780	20,93	3	75·5	±0	"	86·45	261,500	9258	252,250	207,470	9500		4·568	0·080	36·54
6	51,380	24,02	3	88·5	±0·2	"	101·3	306,400	10,620	295,780	224,400	11,190		4·568	0·075	34·26
7	55,030	25,72	3	97·3	±0·3	"	111·14	337,000	11,370	325,630	270,600	12,390		4·573	0·075	34·30
8	62,640	29,28	3	109	±0·4	"	124·8	377,500	12,940	364,560	301,920	13,820		4·573	0·072	32·91
9	62,640	29,28	3	115	±0	"	131·7	398,400	12,940	385,460	322,820	14,780		4·620	0·071	32·80
10	-	-	-	-										4·620	0·480	221·8

Bar: reading at time of seal 75·655
·0444
75·699 @ 26·4 °C.
26·4 × 0·00017 × 75·7 = ·3140
76·278 @ 0°C.

Bar: reading at culmination 75·660
·0444
75·704 @ 27·8 °C
27·8 × 0·00017 × 75·7 = ·3558
75·268 @ 0°C.

Res: of Galv. @ temp. of B (26·4°C) 5523 = at time of seal. N.B. This includes 14 = added for one side for multiple bal.
D.B. H.B. Diff. Galv. 2 each
5521 ÷ 2 = 2760·5 = each coil.

Res: of Galv. @ temp of B (28°C) 5540·5
when culminating 3·3
(28 − 26) = 2 × 0·03 = 0·06 × 55 = 3·3 5543·8
2·4 bal
5541·4 ÷ 2 = 2770·5 = . .

The red wire is soldered to the end of the outside cylinder
" black " " " " " " " inside "
" yellow " " " " " " " " middle between " "

Sensibility of Diff. D.B. H.B. Galv. such that a change of 2 in bal: produces 1 div. deflation. Scale read with aid of lens

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H_2O should boil @ 99·76 °C. at pressure of 75·35 cms Hg.

Temp. observed in water bath in ebullition 99·05C
correction for Therm. + ·6
Corrected indn of Thermometer 99·65 Std. # 1.

0·000 1623 × 25·1 = 0·004073

Temp. of Water bath at time of sealing 23·65
Std. # 1 Thermometer correction − 0·1
23·55
278
Abs. temp. 296·55

Took a tube similar to that sealed into bulb, with same attachment (open one) and found that its contents in Hg. were 5·281 gms ÷ 13·596 = 0·388 c.c.

$75 \div 0.388 = 193.3 \quad \frac{1}{193.3} = 0.005177$

$3\beta = 2.8 \times 10^{-5} \quad t = 5.0 \times 10^{-5} \quad 3\beta t = 8.4 \times 10^{-5}$ } 0·01357

Experiments on the temperature-coefficient of Copper.

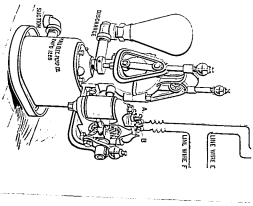
13th Apr. 1890.

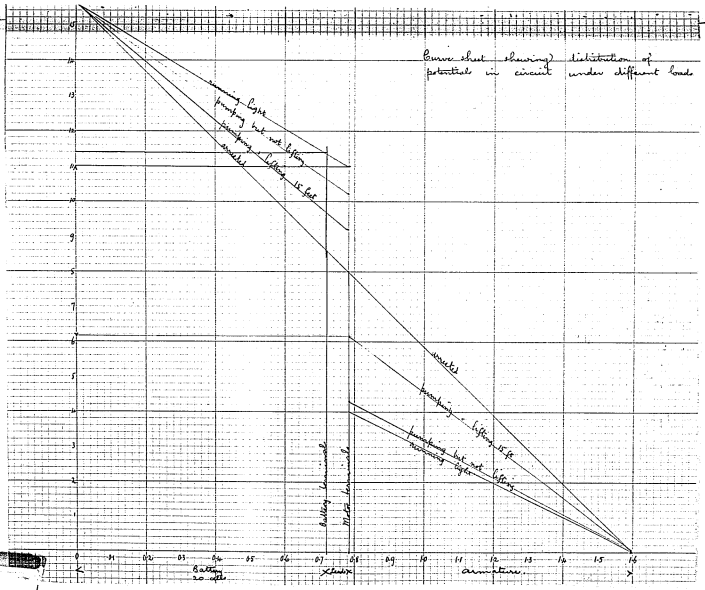
The entire air-thermometer apparatus was dismantled on the 10th, and all its parts cleaned, and examined. The mercury was filtered, and the calibrator index tube of diam: 0·303" (0·770) ext, and 0·207" (0·526) internal, replaced by a longer one of diam 0·295" (0·75) ext. and 0·219" (0·556) internal. The bulb itself was cleaned, and a new tube sealed into it about 16 cms long, with a total equivalent capacity equal to 20 cms. Its diam is 0·24" (0·6) externally, 0·07" (0·18) internally, and its total contents 0·4 c.c. The bulb was then raised to a temp. of about 200°C for an hour under a vacuum to withdraw all moisture from the interior and finally filled with dried air. The apparatus was then remounted. The fiducial mark for the mercury column in the vertical tube leading to the bulb was fixed at a point where the narrow tube above described was joined to one of larger calibre 0·273" ext. 0·205" int. diams. The object of this was to secure less friction in the rising or falling column, this having been a source of inconvenience in the previous measurements, and possibly also of error.

It was then decided to compare the indications of the instrument with those of the mercurial standard thermometer and the following series was taken with that object. The heating bath was of distilled water, raised to the boiling point.

No. of Obs.	Times	Temp. of Room + Bridge	Obsd. res. of Galv. coils	Obsd. res. of 1 ft. of tube. Adopted	Obsd. res. of 1 ft. of tube. Adopted	Ratio of change	Balance between coils	Ratio to 1st	Bath: Ready.	Rise of Hg.	Temp. of Hg.	Coeff. for temp. Hg.	Corrected rise of Hg. at 0°C	Coeff. K.
1	20·40		20·281	10·1815	10·1680		2 =	1·0009	10·716		25·1°	1·00407	10·760	
2	21·142				1·0014				12·689	1·972	25·3	1·00411	1·964	0·02605
3	·50								15·612	4·896	25·6	1·00416	4·875	0·04147
4	·55								18·884	8·168	26·	1·00422	8·134	0·10795
5	22·01		1	1	1				22·786	12·070	26·4	1·00429	12·020	0·1595
6	·11		2	2	2	Mean. 1·293			27·570	16·854	26·7	1·00433	16·788	0·2228
7	·22		9	8	9				29·894	19·088	27·0	1·00438	19·010	0·2523
8	·25		5	9	5				30·112	19·396	27·2	1·00441	19·312	0·2563
9	·32		20·254	13·128	13·170		9 =	1·0032	30·258	19·542	27·2	1·00441	19·460	0·2582
					1·0032				19·543	108·958				
										90·144				
										198·430				

No. of Obs.	1+(t−1)·0041	Corrected Normal Abs. temp	Corrected Abs. temp at obs.	Temp. °C by air Thermom.	Rise of temp. °C by air	Res: added for balance	Res. in Galvanom.	Res. of end Galv. coil	Ratio	Ratio of res.	Coeff. per cent
1	1·00035[illegible]	296·55	296·85			12·95 (a)	4056	2761	0·6092		
2	1·00085[illegible]		296·65	304·38	7·53	1181 (b)	3943	2762	0·70048	1·03903	0·03708
3	1·00085[illegible]		296·81	306·01	9·46	1011 (c)	3774	2763	0·7321	1·07528	0·07983
4	1·00[illegible]		296·98	329·05	32·50	845 (d)	3609	2764	0·7659	1·12510	0·03846
5	1·00216[illegible]		297·19	344·59	48·04	655 (e)	3420	2765	0·80848	1·18788	0·03906
6	1·00302[illegible]		297·45	363·72	67·17	447 (f)	3213	2766	0·86088	1·26466	0·03910
7	1·00342[illegible]		297·57	372·65	76·10	380 (g)	3148	2768	0·87928	1·29161	0·03832
8	1·00361[illegible]		297·58	373·55	77·30			2769	0·87960	1·29217	1·00377[illegible]
9	1·00350[illegible]		297·59	376·43	77·88	378·5 (h)	3148·5	2770	0·87978	1·29242	1·00373[illegible]
			2377·82	2768·68	396·28						
			297·2·40	297·24							
				396·28							


LINE WIRE C
FIELD WIRE F
B
Wheatstone's bridge
Galvanometer
Battery


Curve sheet showing distribution of potential in circuit under different loads
pumping light
pumping but not lifting
pumping & lifting is fair
works
works
pumping & lifting is fair
pumping but not lifting
pumping light
Battery resistance
Motor resistance
0
·01
·02
·03
·04
·05
·06
·07
·08
·09
·10
·11
·12
·13
·14
·15
·16
Battery
Armature
X

Test of 20 Edison-Lalande cells of the double plate 300 chour pattern on a Hall pump motor.

16th Apr. 1890.

The small Hall pump has two cylinders which are driven from a crank shaft between them, which is itself driven by a worm on the motor shaft. The motor is geared 50 to 1, and ordinarily makes 2500 revs per min: when supplied by 100 volts. The motor drawings and calculations are shewn on pages 144-3 book II. The stroke is 1·75" (4·444) and the cylinder diam: 1·75" (4·444) area 2·41 sq in 15·48 sq cms, so that at each revolution of the shaft 8·444 c.in. (137·5 c.c) are discharged. A gallon being 3786 c.c. = 0·03637 gallons per rev: n revs per min: are therefore 2·178 n gallons per hour. Each revolution also lifts 0·3 lbs: so that n revs per min at a lift of f feet are equivalent to 0·3 . n f. foot-lbs per min.

Speed of shaft r.p.m.	Capacity per second	P.D. at M.T.	Current in arm:	Current in field	Power absorbed in arm:	Power absorbed in field	E.M.F.	Res: battery	Res: leads	Power generated by battery	Power adsorbed by battery	Power generated in arm:	Eff: of arm:	Eff: of arm:
		volts	amps	amps	watts	watts	volts	ohms	ohms	watts	watts	watts		
70 p.m.	Discharge	12·0	3·1	0·75	37·2	9	15·8	0·72	0·0650	57·0	9·1	9·5	0·84	
57	Half charge	11·0	4·48	0·68	49·3	7·5	16·0	"	"	82·5	20·6	7·4	"	
0	Amalg	7·9	9·7	0·6	76·6	5	16·0	"	"	164·8	83·3	0	0·81	
59	Pumping 40	10·2	5·3	0·66	53·1	6·7	16·0	"	"	95·3	27·9	5·9	"	
34	" 15 ft	9·2	7·00	0·6	69·9	5	15·6	"	"	128·0	52·8	3·04	"	

Speed of shaft r.p.m.	E.M.F	P.D. at battery terms	P.D. at motor	E.M.F. generated	fall of pot: in battery	fall of pot: in arm:	Power wasted in arm:	Power wasted by accumulator	Nett eff: E.M.F. / E.M.F.	Gross eff: E.M.F. / pot: at M.T.	Speed of calculation shaft for 100 volts	E.M.F. generated per revs	Total revs of wt	
70	14·8	12·8	12·0	9·5	2·93	2·5	7·75	29·46	71·7%	79·15	3500	272×10^{-3}	0·72	
57	16·0	12·3	11·0	7·4	4·05	3·6	16·1	33·16	46·3	67%	2850	2·59	0·065	
0	16·0	8·6	7·9	0	8·09	7·9	76·6	0	0	0	0		0·81	
59	16·0	11·3	10·2	5·9	4·68	4·3	22·8	31·2	36·9	58%	2550	2·31	1·595	
34	15·6	10·1	9·2	3·04	6·444	6·16	46·8	23·1	19	33	1700	1·79		

Succeeded in obtaining fair pumping through 100 feet of iron pipe 3/4" int: diam: laid horizontal and 15 feet vertically at 34 revs per min = 7·4 gallons per hour. This was the limit. A few inches higher pumping stopped the motor entirely. An improvement can be made in the compounding of the fields, but otherwise it will be necessary to use a finer thread on the worm.

Trial of the Melting point of a fine Platinum wire fuse for Battery purposes.

16th Apr. 1890. Platinum wire 0·0025" (0·00635) in diam, suspended horizontally in air

Trial No.	Length wire cm	Ghach	Amp.	P.D. across "Volts"	Res. of wire	Res. per cm.	Ratio of Res. to wire cast	Condition	Energy per cm. Watts	Energy per cm. Sp. cm per cm	Energy per sq. cm			
1	22.85	0.035	0.870					—		0.01995				
2	22.85	0.045	0.237					slightly shade						
3	22.85	0.160	0.808					red ht						
4	22.85	0.180	0.909					broke						
1	8.80	0.06	0.303	2.8	9.24	1.050								
2		0.09	0.455	4.25	9.34	1.062								
3		0.11	0.556	5.55	9.99	1.135		broke white						
1	6.07	0.06	0.303	1.75	5.75	0.947								
2		0.09	0.455	2.9	6.37	1.050								
3		0.11	0.556	3.85	6.92	1.140								
4		0.16	0.808	6.1	7.55	1.244		bright red						
5		0.180	0.909	6.8	7.48	1.232	1.30	broke (fused)	1.018		50.9			

Experiment on the Local Action of Zinc Plates in NaHO solution.

To ascertain how far the cast and rolled zinc battery plates suffered respectively from local action from of each were immersed in solution (of NaHO in water) of the usual strength, on the 17th Apr. 1890. their weight were as follows:—

Rolled zincs nos 1 303.5 grammes
2 315.75 "
3 317.5 "
4 301.5 "
} 619.75, 633.25, 619.25

Cast zincs - 5 1232.75 "
6 1229 "
7 1235.25 "
8 1303. "
} 2462.2, 2463.2, 2538.7

Weights of these plates (dry) at different dates

Plate No.	27. III. 90	31. III. 90	29. III. 90	8 V. 90 Stim. Res. Exc.	27. V. 90	27. V. 90 immersed 4 days							
		4 days	12 days	21	60								
1	303.5	303.3	303	297.1	307.6	302							
2	315.75	315.8	314	308.8	313	311							
3	317.5	317.5	316	310.2	314.3	312							
4	301.5	300.8	300.25	300.3	307.8	295.75							
	12.38.25	12.36.4	12.35.25	1210.4									
	309.56	309.1	308.32	302.6									
5	1232.75	1233	1232	1226.5	1232.5	1231.5							
6	1228.	1227	1226.25	1219	1221.4	1224.							
7	1235.25	1234.5	1233.5	1226.2	1228.9	1231							
8	1303	1302.8	1302.25	1297.0	1296.3	1300							
	4999.0	4997.3	4992.0	4968.7									
	1249.75	1249.3	1248.0	1242.2									
Diff.		0.46	1.24	7.0									
		0.45	1.75	7.5									

$$3\beta = 0.0001815 \frac{p_1}{p_0} - \frac{p_1 - p_0}{p_0 (t_1 - t_0)}$$

#1

$$\frac{0.0001815 \times 108.6705}{108.6705} - \frac{108.8705 - 108.6705}{108.6705\,(132.8)}$$

$$0.00017783 - 0.0001521\overset{2.2}{7}$$

$$= 0.0000\underset{\sim}{2566}$$

#2

$$\frac{0.0001815 \times 84.4191}{86.1201} - \frac{86.1201 - 84.4191}{86.1201 \times 132.8}$$

$$0.00017791 - 0.0001148\overset{(1.7010)}{7}3$$

$$0.0000\underset{\sim}{2918}$$

Standardisation of 4 Clark Cells and 1 Wiet Daniell cell belonging to Messrs Bergmann & C.

18th Apr. 90.

Potentiometer employed. Our two Mainhard standard cells in perfect agreement. Temp. 24·1°C by their thermometer. = 1.4280 volts. @ 24°C.

Wiet Daniell cell. Temp. of solution in central bottle 21·4°C 1.0774 v.

Later " " " 22·4° 1.0750.

" " 23·3° 1.0770.

Reversed Potentiometer readings to check accuracy, accordance perfect.

Cell	1st series	Discrepancy	2nd series	Discrepancy	3rd series	Discrepancy	Mean Discrep.
Our Standard	1.4280		1.4280		1.4280		
Bergmann 1	1.4296	+0.0016	1.4290	+0.0010	1.4286	+0.0006	+0.0011
" 2	1.4130	−0.0150	1.4120	−0.0160	1.4124	−0.0156	−0.0152
" 3	failed	—	failed		0.4074	failed	
" 4	1.3490	−0.0790	1.3490	−0.0790	1.3500	−0.0780	−0.0787

Temp. of air 23°C.

Cells in box with no thermometer hole, in room for one hour, but exact interior temperature uncertain.

Measurement of the Coefficient of Expansion for the glass bulb employed in the experiments on conductivity

18th Apr. 90.

Two bulbs of the same description and quality of glass were blown and drawn out at one end to a fine tube. These bulbs were then filled with good mercury and their temperature when quite full noted. They were then weighed. They were next heated in mercury on a sand bath to a considerable temperature and after cooling again weighed. Their necks being above mercury in the heating process they disgorged all the excess due to dilatation. Finally the bulbs were broken at the neck, emptied and the glass weighed, the entire results being as follows.

No. of bulb	Weight of glass	Temp. std. when full	Ht. corrected for thermom. stem	Weight of Hg at low temp.	Weight of Hg at high temp.	Temp. std. when full hot.	Ht. corrected for thermom. stem	Weight of Hg at high temp.	Weight of Hg contained	Loss of Weight	3β	Mean 3β	Weight
1	10.9305	25.5°C	25.4	119.801	108.8705	157.°C	158.2°C	117.6010	108.6705	2.200	2.0266×10^{-4}	2.0266×10^{-4}	1
2	6.6809	24.6°	24.5°	92.8010	86.1201	"	"	91.100	84.4191	1.7010	2.9182×10^{-4}	2.9182×10^{-4}	2

Giving weight 2 to obs. 2 and weight 1 to obs. 1

The mean result is $3\beta = 2801 \times 10^{-8} \pm 113$

1st obs	2566	Mean 2801	v	235	v^2	55225
v^2.	2948		v	189		14161
					Σv^2	69386
					Σpv^2	83547

$\sqrt{\ } = 289 \times 0.67449 = 195$

$\div \sqrt{3} = 1.732 = 113$

Reduction of Ballistic Galvanometer to Absolute Measure.

Scale	Temp.	Earth's Field	Reduction factor	Q	No. of turns	Mean Throw	τ	Q	Q from Table	Temp.	Mean
Lab.	23°C	2·583	$\frac{2.583}{1.4\times10^{-3}}$	1.4×10^{-3}	5	103·5	±0·1		1.4×10^{-3}		
	23°C	2·583	$\frac{2.583}{1.4\times10^{-3}}$	1.4×10^{-3}	5	103·5	±0·1		1.4×10^{-3}		
									1.4×10^{-3}		

$$\Phi_1 = \frac{Q \times \tau \times}{2\pi N}$$

$$\Phi_2 = \frac{\Omega}{10 \times r}$$

Set No. 1 — Inductance coil

No.	Deflection Galv. in ½ in. scale	Temp.	Correction E. Magnet	No. of turns	Mean Throw	Dev.	Res. of Galv. cct	Q	Φ	Φ_2
1	0	0	0	–	–					
2	6·40	0·11655	0·08868	1	5	–	5250	5.703×10^{-3}	51·8	42·
3	8·20	0·14796	0·18465	1	1	–	.	1·141	10·4	8·4
4	12·20	0·21650	0·16230	1	2	–	.	2·282	20·8	16·8
5	21·	0·37881	0·28860	1	5	–	–	5·703	51·8	42·
6		0·10081	0·585	1	10	–	–	11·405	103·6	84·1
7		0·0422	0·964	1	8	–	–	14·83	134·7	109·3
8		0·0422	2·693		32	–		36·5	331·6	269·2
9		0·0975	4·910	1	45	–	5250	51·33	466·3	378·6
10		4·10	20·70	1	57	–	.	65·0	590·4	479·4
11		0		–	–	–	–	–	–	–

Set No. 2 — Condenser

No.	Deflection Galv.	Temp.	Correction E. Magnet	No. of turns	Mean Throw	Dev.	Res. of Galv. cct	Q	Φ	Φ_2
1										
2	2·2282	0·0422	0·0422	2	2	±0	5250	2.282×10^{-3}	1198	
3	3·42	0·0633	0·0633	2	3	±0	.	3·42	1795	
4	5·133	0·0844	0·0844	2	4·5	±0	.	5·133	2695	
5	10·84	0·1688	0·1688	3	4·5	±0·5	–	10·84	569·1	
6	17·68	0·2532	0·2532	2	15·5	±0·5	.	17·68	9282	
7	38·78	0·5066	0·5066	3	3	–	.	38·78	20360	
8	64·16	1·0132	1·0132	3	8	±0	(32,250×1) 32,250	64·16	33,680	
9	62·26	2·0264	2·0264	6	6	±0·5	32,250	62·26	32,680	
10	42·43	4·0528	4·0528	6	94	±0·5	32,250	42·43	22,280	
11	58,130									

No.	Corrected Φ	Φ_2	Set No. of turns	Mean Throw	τ	Res. of Galv. cct	Q	Reduction factor	Φ	Correction for winding space	Corrected Φ	$\Phi - \Phi_2$	L in cm	Ratio of Bridge	Resistance Measured	Coeff.	Inductance Henries
1	–	–	–	–	–	–	–	–	–	–	–	–	–				
2	1342	62·7	2	16	±0	5250	1.025×10^{-3}	525	9,582	277	9305	7963	365	1000/100	4·575	0·101	46·2
3	2011	94	2	17·5	±0·4	.	1·936	.	10,480	416	10064	8053	369	27·4	4·639	0·099	45·94
4	3020	141	2	36	±0·8	.	4·107	.	21,560	613	20,937	17,917	820		4·655	0·098	45·63
5	6377	298	3	73·5	±1·2	.	8·385	.	44,020	1317	42,703	36,326	1660		4·651	0·097	45·12
6	10400	486	2	119	±1·9	.	13·57	.	71,230	2145	69,052	58,652	2690		4·668	0·093	43·42
7	22810	1066	3	44·3	±0·5	30,250	50·33	.	152,900	4712	148,188	125,378	5740		4·690	0·090	42·47
8	38,810	1814	3	77·7	±0·3	.	88·64	.	269,200	8019	260,181	221,371	10,130		4·707	0·070	32·83
9	38,810 (42,280)	2290	2	93·5	±0·4	.	106·75	.	319,200	10120	309,080	260,060	11,940		4·704	0·038	18·80
10	62,890	2939	2	109·5	±0·4	–	124·9	–	377,900	12,095	364,905	302,015	13,830	27·52	4·716	0·037	18·780
11	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4·713	0·095	44·780

Measurement of Inductance of Iron Ring at right angles to the Earth's Field.

Direction of Magnetic Axis

	Ratio	Coeff.	Inductance
	1·1205	∞	
1			E. M. F.
2			Comp. +110
3			3 - +110
4			2 + +110
5			1 - +110
6			1 Comp.
7			110

Reduction of damping to absolute measure

Temp.	Temp.	E.M.F. at 1 volt	Bands	a	No. of Bands	Mean Thickness	Pos. dev.	a per dev.
16°C.	22°C	1·420	1000	1·420 $\times 10^{-3}$	7	123·6	± 0·3	$1{\cdot}157 \times 10^{-3}$

Period of one complete swing of bulkiness results 20 sec. exc.

$$\rho = \frac{5250}{578} \times \frac{1{\cdot}157}{4} \times 9{\cdot}074\ \psi = \frac{30{,}250}{578}\ \psi = 52{\cdot}35\ \psi$$

Measurement of the Induction of Rings at night angles of magnetic dip (Prof. Stark)

No. of obs.	Position of Ring	Correction	Corrected φ	Coil #1 No. of Bands	Mean Thickness	Coil (Inductometer) Pos. dev.	Ratio of Gilbert cst	a	φ	Σ	Coil #2 No. of Bands	Mean Thickness	Pos. dev.	Ratio of Gilbert cst	a	φ
1	0°·00'	-		+	0	-	5250	"	"	-	#	θ	-	5250	-	-
2	6°·20'	0·1139	0·0869	1	0	-	-	"	"	-	1	0	-	"	-	-
3	8°·40'	0·1524	0·1849	2	7·5	± 1·2	"	$8{\cdot}678 \times 10^{-3}$	78·82	64	3	6·7	± 0·3	-	$7{\cdot}75 \times 10^{-3}$	4·69
4	30°·20'	0·5851	3·4495	1	13	-	-	20·82 "	189·1	153·5	3	16·2	± 0·7	"	18·51 "	9·718
5		0·195	0·985	3	73	± 1·4	-	84·44 "	767.	622	3	39·7	± 1·0	"	45·93 "	24·110
6		0·391	1·554	2	7	± 0	30,250	8·098 "	423·8	344	2	18	± 0	30,250	20·82 "	42·980
7		0·670	3·384	1	7	—	"	" "	423·8	"	2	21·8	± 1·0	"	25·22 "	76·290
8		0·950	4·798	1	7	-	"	" "	423·8	"	2	23	± 0	-	26·61 "	80·500
9		0·910	9·648	-	-	-	—	" "	-	-	2	27	± 0·9	"	31·24 "	94·500
10	-	0	0	-	-	-	"	" "	-	-	-	-	-	-	-	-

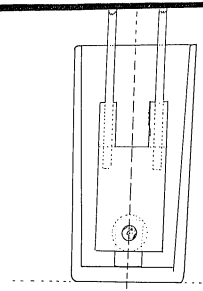
No. of Obs.	Correction φ	Corrected φ	Coil #2 No. of Bands	Position Mean Thickness	Coil Pos. dev.	Ratio of Gilbert cst	a	Φ	Correction for refraction	Corrected Φ	Φ − φ	Σ in mm	Ratio of Bridge	Mean Thickness	Pos. dev.	Ratio of Gilbert cst	a	Φ
1	-	-	0	15·5	±0·7	5250	-	-										
2	-	-	4	15·5	± 0·7	"	17·93	94·10		94·10	94·10	430	10000/100	4·490	0·112		5·02	
3	4·560	213.	4	148·4	± 0·3	-	56·0	294,400	1668	296,068	231,170	1060		4·490	0·113		50·74	
4	10,890	509	5	135·8	± 0·6	-	157·1	824,460	3986	828,446	678,580	3095		4·505	0·118		53·15	
5	27,020	1263	3	333	± 0·4	"	385·3	2023,300	9888	2032,988	1655,590	7570		4·495	0·108		48·65	
6	70,560	3298	2	93	± 0·0	30,250	107·6	325,500	2588	2993,670	2924,210	10500		4·495	0·072		32·37	
7	85,480	3996	2	114·5	± 0·4	"	132·5	400,900	31,200	369,500	2842,020	13,000		4·463	0·073		32·88	
8	90,190	4216	2	121·5	± 0·4	-	140·6	425,300	33,020	392,280	3020,090	13,830		4·449	0·055		24·47	
9	105,900	4948	2	138	± 0·0	"	159·7	483,100	38,750	444,350	3388,450	15,500		4·432	0·050		22·46	
10	-	-	-	-	-	"	—	-	-	-	-	-		4·432	0·031		13·74	
														4·603	0·110		50·63	

Reduction of Observations to other measures

Source of E.M.F.	Temp	E.M.F. of Cell	Resist.	Q	Mag. of Magnet	Mean Mag. Moment	Mag. Field	Q. from Mag.
2 G cells	22.5°	2.159	0.409 Ω	1.1645 ×10⁻⁷	5	101.6	1.18	1.151 ×10⁻⁷

Measurement of the Inductance of Things in the Direction of Magnetization (Ewing)

No.	Time	Alternator	Galvanometer	Lamp	Current	No. of Turns	Mean Thickness	Time	Q	Mass in gm	φ	cos φ	1.257 × turns / cm.	H	μ	Resistance Bridge	Resistance Coil	Reactance	Inductance Henries	
Wrought Iron																				
1	14.40	∞	0	0	0	–	–	–	–	5250 gm	–	–	–	–	–	1000/100	5.805	0.350	203.2	Res. of Iron 0.27 Ω
2	.50	14.40 to 1.10	6°.40'	0.1169	0.098	4	103.6	± 0.3	110,250 ×10⁻⁷	"	1062	879	12.10	1.065	825.5	1000/100	5.807	0.350	203.3	
3	.55	2 - -	16°.30'	0.2462	0.233	6	90.5	± 0.7	104.2 -	30,250	5455	44.29	18.4	2.70	16400	1000/100	5.824	0.175	101.93	
4	15.20	1 - - -	38°.0	0.7513 0.150 0.152	0.089 0.086	4	177.3	± 0.2	201.1 -	30,250	8660	8670	39.70	7.13	12160	1000/100	5.834	0.140	81.66	
5	.35			0.22	1.11	3	66.1	± 0.5	76.09 -	105,250	13,850	11,240	66.70	13.14	839	1000/100	5.8444	0.090	52.61	
6	.50			0.540	2.728	3	84.3	± 0.3	97.04 -	"	14,670	14,340	34.03	33.0	435	1000/100	5.8544	0.037	21.66	
7	16.00			0.853	4.31	3	90.5	± 0.2	105.2 -	"	18,970	15,400	23.3	52.17	295	1000/100	5.980	0.025	14.75	
8	.10			0.9932	1.0[illegible]	2	98.5	± 0.4	113.4 -	"	20,650	16,760	11.9	60.7 121.4	276 138	1000/100	6.023	0.015	9.034	
Soft Iron																				
1			0		7	6.8	2.03	–	5.250 gm				12.014	0		1000/100	5.677	0.056	32.8	Res. of Iron 0.245 Ω
2			6°.40'																	
3			16°.30'		3	6.8	± 0.3	7.829 ×10⁻⁷	"	7.4	57.7	4.25	1.060	54.4	18.8	1000/100	5.855	0.056	32.8	
4			38°		3	19.7	± 0.3	22.68 -	"	22.68	184.1	5.56	2.69	68.4	11.46	1000/100	5.883	0.057	33.54	
5			0.222		4	114.9	± 0.4	132.3 -	"	120.2	975.6	11.99	7.09	137.6	7.26	1000/100	5.938	0.0564	31.53	
6					4	72.1	± 0.3	83.0 -	30,250	43.44	352.7	28.91	13.37	263.8	3.70	1000/100	5.994	0.029	31.78	
7					3	72.0	± 0.4	82.9 -	55,250	79.25	643.4	15.01	32.85	195.9	5.16	1000/100	5.916	0.033	19.72	
8					3	45.2	± 0.1	52.04 -	105,250	94.76	769.4	11.79	51.9	148.2	6.73	1000/100	6.033	0.027	16.29	
9					2	58.5	± 0.4	67.34 -	105,250	12.260	99.52	6.48	60.4 120.8	164.8 82.4	12.1	1000/100	6.200	0.017	10.71	
Test Bar																				
1			0		–	–	–	–	5.250				13.785	–		1000/100	5.858	0.059	34.57	Res. of Iron 0.28 Ω
2					3	7.3	± 0.3	8.40	–	7.63	62.0	4.0	1.212	51.2	19.5	1000/100	5.867	0.060	35.20	
3					3	23.3	± 0.3	26.82	"	24.3.6	197.7	5.05	3.07	64.4	15.5	1000/100	5.877	0.065	31.21	
4					2	2.85	± 0.4	32.75	30,250	1296	1092	10.13	8.12	129.6	7.82	1000/100	5.838	0.061	35.62	Res. 2.21
5					2	117.5	± 0.4	135.3	5250	1224	998	24.4	15.3	370.2	2.70	1000/100	5.901	0.073	43.08	
6					4	115.8	± 0.6	133.3	30,250	8976	5664	3.05	37.59	289.5	3.45	1000/100	5.929	0.035	20.74	
7					3	121.7	± 0.9	140.1	55,250	13390	10,880	2.39	59.39	209.1	4.78	1000/100	6.040	0.026	15.71	
8					3	73	± 0	84.04	105,250	15300	12,420	1.656	121.4	146.6	6.82	1000/100	6.140	0.014	8.97	
9					2	88	± 0.8	101.3	105,250	18,440	14,970	6.54	60.4 138.2	216.6 105.3						



Vertical section through axis of new standard Meter bottle showing zinc in place.

Full size.

Measurement of Resistance of new meter bottles.

12 bottles were made up on Friday 18th April, with laboratory solution and zinc fresh from Silod lake. 1.11 The object of the test was two-fold. 1st To ascertain how much difference would be produced in the resistance of a bottle if the plates were used fresh from the factory without amalgamation. 2nd The difference between the resistance of bottles of two different temperatures.

No. of bottle	Weight empty 18. IV.	Dist. Weight 19. IV.	Sum	Discrepancy 5 - 5	Weight empty 21. IV. 90	Dist. weight 21. IV. 90	Sum of Simple weights	Discrepancy 5 - 5	Gain	Loss	Shunt	Assumed for 1st o	Rise of bottles.
1	51·1626	102·3644			51·0010					0·1626	∞		
2	50·8815		102·3451	+0·0013	51·3725	102·3743	102·3735	−0·0005	0·4910				
3	50·9215				50·7390				0·4178		∞		
4	51·3131	101·6345	101·6343	−0·0002	50·8815	101·6215	101·6205	−0·0010		0·2316			
5	51·0472				51·1180				0·8708				
6	50·3139	101·3611	101·3611	0	50·2467	101·3670	101·3647	−0·0023		0·0672	2ω	hot	
7	50·0057				50·2022				0·3370				
8	50·5572	100·5624	100·5624	0	50·2255	100·5672	100·5677	+0·0005		0·3317	2ω	hot	
9	50·4333				49·9772					0·4561			
10	51·1231	101·5563	101·5564	+0·0001	51·5585	101·5620	101·5617	−0·0013	0·4614		2ω	cold.	
11	51·6575				51·6985				0·4400				
12	51·0275	102·4559	102·4959	+0·0392	50·6990	102·4985	102·4975	−0·0010		0·4385	2ω	cold.	
13	51·5018				51·1570					0·0448			
14	51·6929	103·1950	103·1947	−0·0003	51·7225	103·1795	103·1795	± 0	0·0296		2ω	~~hot~~	
15	50·3799				50·4700				0·1021				
16	52·5905	102·9620	102·9624	−0·0006	52·3020	102·7760	102·7760	± 0	0·2	0·2885	2ω	hot	
17	51·5945				51·8160				0·2215				
18	51·9093	103·5020	103·5031	+0·0009	51·5460	103·3590	103·3610	+0·0020		0·3643			
19	49·5600				49·9920					0·3680	2ω	cold.	
20	51·5570	101·4080	101·4080	−0·0010	51·7865	101·2770	101·2775	+0·0005	0·1995				
21	51·9675				51·6190					0·3185	2ω	cold.	
22	51·4016	103·3691	103·3691	−0·0007	51·6830		103·3220	−	0·2814			cold.	
23	50·2592				Avg. 7970					0·4622	∞		
24	51·0576	101·3198	101·3188	−0·0010	51·5640	−	101·3220	−	0·4862				

The hot box had a temp: of about 58° F and the cold box about 42° F. but the temperature failed in the hot box for a large part of the time. The current was supplied from 1 KHO cell through all the bottles in series and 60ω externally) or about 10 milliampères. The test lasted from 18 o'clock 18th Apr. to 8 o'clock 21st or 64 hour. At the end of that time #5 & 13 & in the cold box & 9 & 10 in the hot box were found in good condition, while all the others were more or less smutted. It was also observed that the black lead figures on the sides of the unamalgamated plates, put on at time of weighing were thickly covered by deposit, much more thickly than on any other part. This was not the case with the amalgamated plate.

This series was taken under favorable conditions. The apparatus was all in good order. The column of mercury in the bulb tube was tapped before every observation, although no friction could be detected. Height of meniscus nearly 1 mm.

Barometer at 19.06 time of reading 76.520 @ 66°.5
index error .0444
76.4756 @ 19.0°.C
$19.0 \times 0.00017 \times 76.56$ 0.247
76.229 @ 0°.C 76.317 + 2.8647 = 79.1817
0.237

Barometer at culmination 76.64 @ 73°.5
.0444
76.596 @ 22.8°
$22.8 \times 0.00017 \times 76.7 =$ 0.297
76.299 @ 0°.C.

No difference in reading observable when the mercury exceed fiducial mark in upward or downward direction.

$t = 300$ $K = 1/15 \cdot \frac{0.14}{0.14} = \frac{0.14}{15} = 0.0093$

$3\alpha = 2.8 \times 10^{-5}$

$3\alpha t = 84 \times 10^{-5} = 0.0084$ $3\alpha t + K = 0.0177$

Obtd temp. of bath when reading 16.75°.C by thermo. 81
.07
16.68°.C corrected reading
273.7
290.38 - abs temp.

Since an error γ at v' gives only, introduces an error of $\frac{\gamma}{v}$ into the coefficient, it follows that the weight of v is $\frac{1}{v^2}$. Also the curve of this method (probably) measures directly with v so that on this account the weight of an observation of $\frac{1}{\sqrt{v}}$. Hence finally the weight of an obs is $\sqrt{v}$. The following table gives results

No.	Coeff. $\times 10^{-4}$	N	$\sqrt{N}$	Δt	$N\sqrt{N}$	$(N\sqrt{N})$ Coeff	General Mean	v	v^2	pv^2	$\frac{v}{(\sqrt{N}\sqrt{\Sigma N})}$	$\frac{v}{\sqrt{\Sigma p}}$
1	0.4097	27.4	5.27	11	5.27	24.120		+0.00558	33.64 x10⁻⁶	177.3 x10⁻⁶	0.1509	0.02196
2	0.3944	42.6	6.53	2	13.06	5.2020		0.00051	0.261	8.515	× 3.0436	= 0.000735
3	0.4038	45.45	7.52	3	22.56	9.1100		0.00027	0.729	16.450		
4	0.4207	72.25	8.50	4	34.00	13.6900		0.0038	14.44	49.100		
5	0.4063	57.1[illegible]	9.33	3	27.99	11.3750		0.0002	4	12.0		
6	0.4172	105.01	10.25	4	41.00	17.1100		-0.0107	114.49	469.400		
7	0.4080	132.05	11.44	3	33.42	13.6390		0.0015	2.25	7.520		
8	0.4144	139.06	11.81	4	47.24	19.5000		0.0076	57.76	273.900		
9	0.4143	154.17	12.42	4	49.68	20.5800	0.4065	0.0078	60.84	300.230		
10	0.4002	169.94	13.04	4	52.16	21.7400		0.0017	2.89	12.400		
11	0.3976	183.71	13.55	4	53.20	21.1300		-0.0037	1.369	73.900		
12	0.3990	187.68	13.68	3	40.44	16.0100		0.0089	7.921	320.300		
13	0.4022	238.52	15.44	4	61.76	24.6100		0.0075	5.625	315.000		
14	0.4022	240.87	15.19	4	60.76	24.2000		0.0043	1.849	44.800		
15	0.4019	246.82	15.65	4	62.60	25.3500		0.0013	1.849	113.300		
16	0.4070	255.26	15.98	4	63.92	26.0200		0.0016	256	16.200		
17	0.4014	255.26	15.98	4	63.92	26.0200		-0.0005	25	1.960		
18	0.4098	255.26	15.98	4	63.92	26.0200		0.0009	81	5.177.0		
19	0.4097	256.44	15.34	3	46.02	18.8600		0.0023	529	33.810.0		
20	0.4088	267.52	16.41	3	49.23	17.6600		0.0032	1.024	47.130.0		
					909.97	366.9120		0.0023	529	23.520		
					1.67	1.32				2,192.260		
										$\sqrt{2192.260}$ = 0.02196		

General result gives coefficient for 1°C by air-thermometer 0.4065 ± 0.00073

No.	Time	Temp. of Bath	Obtd. air temp. after time allowed	Obtd. air temp. after time allowed	Observed mean of both air temps.	Balance added to reduce to	Ratio	Barometric Reading	Temp. of Hg. col.	Coeff. for temp. Hg. column	Corrected Barometric Reading	Press. of Hg.	Coeff. for air
1	19.06	18°	19.6								76.520	76.47 21	0.1[illegible]
2	20.02	19°	19.5	19.9410	0.924	19.8365	5v	1.00187	9.68	20°	9.0877	78.8[illegible]	0.0[illegible]
3	.06		19.6	19.865	0.0255							82.3235	
4	.22		18.5	1.00711					11.9444	21°	11.0034	2.8807	0.1007
5	.29		19.2						15.8244	21.5°	1.0034.07	15.7694	6.7357	0.3964
6	.35	19.4	19.7						19.4230	21.6°	1.0035.06	19.3621	10.3234	0.4095
7	.45		19.5						23.4470	21.7°	1.0035.22	23.3876	14.3289	0.4027
8	.54		20.2						27.3120	21.9°	1.0035.54	27.2562	18.1765	0.4063
9	21.00		20.3	1	1	1			31.9644	22.1°	1.0035.87	31.8947	22.8710	0.4172
10	.10	19.3	20.3	9	9	9	22v		36.8622	22.3°	1.0036.19	36.7294	27.2904	0.4080
11	.18		21.1	6	6	5			40.8544	22.5°	1.0036.52	40.7053	31.6866	0.4144
12	.30		21.8	5	1	5			44.5714	22.8°	1.0037.00	44.4296	35.5390	0.4143
13	.44		21.5						48.6464	23°	1.0037.33	48.4666	39.6279	0.4002
14	.49	20°	21.5						52.1764	23.2°	1.0037.65	51.9765	42.8570	0.3976
15	.56		21.9						55.6064	23.6°	1.0038.20	55.3938	46.3551	0.3990
16	22.04	20.1	22.1						60.338	23.8°	1.0038.63	60.1058	51.0671	0.4022
17	.12		22.1	1.00096					64.208	24.1°	1.0038.96	63.9588	54.6201	0.4022
18	.21	20.3	22.2	19.9551	19.9644	3g.0645	27v	1.00990	67.820	24.9°	1.0038.79	67.5579	58.3702	0.4019
19	.25		22.1		3g.1155	3g.0945			70.4586	23.8°	1.0038.63	70.2147	61.1770	0.4070
20	.40		22.0			0.0025			70.4286	23.7°	1.0038.47	70.2037	61.1772	0.4097
21	.48		21.5						70.4286	23.7°	1.0038.16	70.2037	61.1772	0.4088
22	.55	20.6	21.5						65.4284	23.6°	1.0038.86	65.2037	56.7672	0.4097
									58.3144	23.6°	1.0038.30	58.1078	49.7872	0.4088

No.	V (1.0038)	(1.0038)$^{-1}$ (1.0038)$^{-2}$	Corrected Normal temperature	Obtd. air temp. at observation	Temp. C by air thermometer	Ratio of temp. C to air thermo.	Pres. reduced for balance	Pres. reduced 19.5°.C.	Pressure of Gas cells	Pressure of Gas cells reduced 19.5°.C	Pressure of Gas cell.	Ratio	Ratio of Pressure
1	1.0000		290.4	290.4	16.7								
2	1.037500	1.000515	290.6	301.5	27.8	11.1	1358 (6)	1358 (6)	2671.5	2672.5	4025.3	0.663025	1.0
3	1.038000	1.001208	290.7	316.34	42.64	25.94	1185 (11)	1185 (11)	2670.5	2680.5	3856.4	0.693[illegible]6	0.9[illegible]8
4	1.135505	1.001853	290.9	330.25	56.35	39.85	980 (14)	979.9 (14)	2688.	2665	3661.9	0.73263	1.03[illegible]6
5	1.139048	1.002476	291.2	345.95	72.25	55.55	800 (18)	800 (18)	2697.	2690	3490.	0.77077	1.0092
6	1.239[illegible]	1.003263	291.4	360.81	89.11	70.41	622 (24)	622 (24)	2700	2695	3317.	0.812.68	1.02370
7	1.245[illegible]	1.004095	291.6	378.77	105.07	88.37	462 (31)	462 (31)	2703	2700	3162.	0.85389	1.02412
8	1.32[illegible]	1.004971	291.8	397.69	123.99	107.29	292 (41)	292 (41)	2706	2705	2977.	0.90863	1.03573
9	1.41[illegible]	1.005895	292.0	413.18	139.48	122.78	-5 (60)	-5 (60)	2710.	2711	-2716	1.00157	1.00167
10	1.465[illegible]	1.006833	292.3	427.87	155.17	137.47	-114 (80)	-114 (80)	2712	2713	-2827	1.04206	1.05[illegible]
11	1.51[illegible]	1.007798	292.5	443.64	169.94	152.24	-215 (100)	-215 (100)	2714	2715	-2930	1.07923	1.0555
12	1.562[illegible]	1.007710	292.8	457.41	183.71	167.01	-300 (120)	-300 (120)	2716	2717	-3017	1.11036	1.0[illegible]
13	1.609[illegible]	1.008322	292.6	465.38	181.68	164.98	-370 (139)	-370 (139)	2718	2719	-2989	1.09944	1.0252
14	1.6[illegible]	1.009166	293.1	489.23	205.53	187.83	-335 (150)	-335 (150)	2719	2721	-3106	1.14164	1.0[illegible]
15	1.7[illegible]	1.009860	293.3	504.29	230.59	213.89	-530 (170)	-530 (170)	2720	2723	-3253	1.19482	1.0962
16	1.7[illegible]	1.010505	293.5	515.57	244.67	228.17	-634 (180)	-634 (180)	2721	2724	-3363	1.23480	1.0356
17	1.804[illegible]	1.010980	293.6	528.96	255.26	238.56	-705 (190)	-705 (190)	2721.5	2725.3	-3481	1.27729	1.0238
18	1.808[illegible]	1.010980	293.6	528.96	255.26	238.56	-840 (200)	-840 (200)	2721.5	2725.5	-3566	1.30840	1.0701
19	1.7[illegible]	1.010980	293.3	528.96	255.26	238.56	-842 (200)	-842 (200)	2721.5	2725.3	-3568	1.30922	1.0719
20	1.7[illegible]	1.010980	293.3	528.96	255.26	238.56	-818 (200)	-818 (200)	2721.5	2725.3	-3546	1.31141	1.0730
21	1.7[illegible]	1.010980	293.3	509.14	235.44	219.74	-705 (190)	-705 (190)	2721.5	2725.3	-3431	1.25890	1.0[illegible]
22	1.6[illegible]	1.008808	293.9	461.22	207.52	190.02	-645 (180)	-645 (180)	2721.5	2725.5	-3270	1.19.185	1.0[illegible]
				9479.25	5254.55	5000.05		12620		59,337	70885.7		
					5254.55	3270 =				5,337			
					9479.25	34.65				70,223.7			

Test of a Material whose samples received from Messrs. Bergmann & Co. are marked V. M. C. No. 1. Received 22nd April 1890.

These two samples were similar and in the form of discs 6·5 in diam and 1·0 thick. Brown glazed superficially) and having the appearance of stoneware. These are very brittle and break by fall of two or three feet. The fracture is irregular and almost cryst-alline, much resembling that of sandstone. In the latter it burns the edge of the tool but it drills readily. The thread it bakes is weak and poor. It is not affected by flames but will not burn long when withdrawn. It soaks by oozing across its surface about as much as slate, and the surface glaze is very easily scratched off even by a common brass pin. The weight of one ~~pin~~ disk dry was 70.475 g. in air. This was left to soak in water. Another piece was buried and a third left on the engine plate. The weight of the disk left in water was 70·476 g. after drying on the 26th April. The weight of the other piece was not taken but they were apparently quite unaffected by their treatment. The heated piece only showed a slight change in color.

Experiments on the Electrolysis of Matta.

see p. 28

23rd Apr. 1890. The same bath and general connections were used with a new matta plate. The mean temp of the liquid between the electrodes was 38°C (100.4°F) and the following readings were obtained. The distance between carbon and matta 5".

No. of Obs.	Lamps in cct.	Voltmeter reading	Current amperes	Amperes per sq. ft	Ohmic reading	res.	P.D. due to res.	P.D. due to counter	res. per sq. ft	Cost of comp. per hour	Cost of res. per hour	Total cost.
1	6	1·8	3·283	5·3	0·65	0·2ω	0·86	1·14	0·125ω	1·18 volts	$ 4·10	10·0
2	8	2·0	4·091	6·5	0·81		0·82	1·18			5·04	10·94
3	10	2·18	5·303	8·5	1·05		1·06	1·12		$5.90.	6·60	12·50
4	12	2·35	5·910	9·4	1·17		1·18	1·17			7·20	13·20
5	14	2·52	6·768	10·8	1·34		1·35	1·17			8·38	14·28
6	16	2·70	7·576	12·1	1·50		1·52	1·18			9·39	15·29
7	18	2·80	8·106	12·7	1·605		1·62	1·18			9·85	15·75
8	20	2·90	8·714	14·0	1·73		1·75	1·15			10·86	16·76
9	22	3·05	9·344	15·0	1·85		1·87	1·17			11·64	17·64
10	6	1·90	8·344	5·3	0·662		0·67	1·23				

24th Apr. Mean temp. 50°C (122°F)

No. of Obs.	Lamps in cct.	Voltmeter reading	Current amperes	Amperes per sq. ft	Ohmic reading	res.	P.D. due to res.	P.D. due to counter	res. per sq. ft.	Cost of comp. per hour	Cost of res. per hour	Total cost.
1	8	1·7	4·24	6·9	0·82	0·18ω	0·76	0·94	0·112ω	1·0 vo	4·80	10·10
2	10	1·88	5·00	8·1	0·99		0·90	0·98		$5·30.	5.63	10·93
3	12	2·0	5·81	9·4	1·15		1·05	0·95			6·33	11·63
4	14	2·2	6·67	10·845	1·32		1·20	1·0		Matta changed frequently.	7·27	12·57
5	16	2·4	7·98	12·5	1·58		1·44	0·96			8·69	13·99
6	20	2·6	8·59	13·46	1·7		1·55	1·05			9·36	14·66
7	22	2·7	9·09	14·26	1·8		1·62	1·06			9·90	15·20
8	8	1·8	4·09	6·4	0·81		0·74	1·06			4·45	9·75

$4.8 x + y = 1.8$
$9 \cdot 09 x + y = 2.7$
$5x = 0.9$
$x = 0.18$
$y = 1.06$

500 dr = in of that brass per hour = 0.112
= 89.6 d × 0.776 = 69.5 d f.

Meter Experiments.

The following measurements were made of the Test No. 8. meter 24th Apr. Res: between slip as follows:-

Obs. No.	Slip	Temp. B.	Bridge Ratio	Res: of std	Leads	Total Res.	Temp. of air in crate	Rate of speed	Corrected to 21·1°C.	
1	Left hand	19°C.	1000/100	48·66	2·36	46·30	20·5°	46·295	46·40	21·1 − 20·6 = 0·6
2	"			48·51		46·15		46·145	46·25	0·6 × 0·311 = 0·2328
3	"			48·42		46·06		46·055	46·16	1·002328
4	Right hand			48·53		46·17		46·165	46·27	
								Mean	46·27	

Balance one strip in the meter against our standard 0·01 ω
This standard was measured on 28th Jany 1890 as correct at 27°C.
7th Feby - - - 7°C.
18th June - - - 14°C.

When compared with lower strip results as follow:-

Obs. No.	Shunt combined	Time	Res: of Galv.	Comparing	Temp. of Std.	Res: of Std. at temp.	Balance	added to	Resistance	temp. of strip
1	Lower	11·30	54·00	0·01 ω	27·1°	0·010039	2832	0·01 ω	0·004983	20·5°C.
2	"	11·45	"	Upper	—	—	270	lower	0·006935	Ratio $\frac{L}{U}$ = 1·01
3	"	13·40	53·91	0·01 ω	20·8°	0·010020	2830	0·01 ω	0·004972	20·6°C.
4	"	"	"	"	"	"	2875	"	0·004932	1·0039
5	"	14·00	"	Upper	—	—	260	lower		Ratio $\frac{L}{U}$ = 1·0039
6										

Balanced Platinoid grid used in carrying capacity of conductors against 0·1 standard Platinoid. held by account to be correct @ 14°C.

Obs. No.	Grid.	Time	Res: of Galv.	Comparing	Temp. of Std.	Res: of Std @ temp.	Balance	added to	Resistance	Temp. air
1	Pat. 6 Coil	15·0	53·92	0·1 ω	20·9°	0·10021	2818	0·1 ω	0·004903	20·4°

Made a comparison test for this & meter by) using the grid with shunt resistance of about 4·70 ω in its circuit.
The test commenced 23rd Apr. 90. 12 o'clock. Current 50 & 60 amp.

Thousand plate	Weight 23 Apr. 90	Sums	Weight gained 23.10.90	How placed	Weight 23 Apr. 90	Sums	Weight gained 23.10.90	Condition	Gain	Loss	Mean
1	50·5625	101·6552	101·656	L.H. Matured	50·2248	101·673	101·673	Nightly smalts	0·3323	0·3145	0·3228
2	51·0927				51·1425		0·017				
3	51·5620	103·3125	"	2 . .	51·2485	103·3195	103·3205	"	0·3135	0·3170	0·3152
4	51·7505				52·0710		0·008				
5	50·9040	103·0145	103·0145	3 . .	50·5860	103·0280	103·0290	"	0·3205	0·3180	0·3248
6	52·1105				52·4420		0·0105				
7	51·0015	102·0525	102·0525	R.H. . .	50·6834	102·0630	102·0630	"	0·33·15	0·3181	0·3231
8	51·0510				51·3796		0·0105				
9	50·7693	102·6923	102·6930	Grid cut	51·1135	102·7065	102·7075	"	0·3412	0·3300	0·3371
10	51·9230				51·5930		0·0125				
11	51·5583	102·9340	102·9340	" "	51·9865	103·9473	103·9482	"	0·3282	0·3050	0·3166
12	51·2757				51·2607		0·0125				
13	52·0705	103·8730	103·8730	" "	52·4025	103·8935	103·8950	Heavily smalts	0·3325	0·3120	0·3223
14	51·8030				51·4910		0·0125				

With a current of $\frac{2 \cdot 9}{0 \cdot 014}$ = 59·2 amp. passing for several hours through the meter, the temp. of the air above was 40°C inside. The temp. of the external air being 26°C.
After several hours of 65 amperes this meter. Internal temp. 42°C ext. 25°C.
" " hour of 75 - - - - - 26° - 20°C

27 − 14 = 13 × 0·03 = 0·39 = 0·010039

2700 / 46·0 — 2700 / 2832
27 46 : 2773 :: x : 0·010039 — 5532 :: x : 0·010039

20·5 − 14 = 6·5 × 0·03 = 0·2016 = 0·0100201

2695·5 / 46 — 2695·5 / 2830
27 41·5 — 55258 :: x : 0·0100201

2695·5 / 2830 / 5525·8 :: x : 0·0100201

2695·5 / 5 / 0·5 / 2767·5

27 41·5 — 2767·5

21 − 14 = 7 × 0·03 = 0·21 — 0·10021

2696 / 2818 / 1 / 5515 — 2699 :: 0·10021 : x

Res: of coil in cir. with both 5·10 465·16 + 2 for both = 467·2
" " " " " " 4·12 488·95 + 2 = 494·0
" " " " " " 13·44 492·24 + 2 = 494·4

467·2 / 0·014 = 9334 × 0·3271 = 3214
494·0 / 0·014 = 10023 × 0·3166 = 3173 } 3189
494·4 / 0·014 = 10030 × 0·3170 = 3179
5·06

467·2 + 2·0 = 48·3 / 0·004972 = 9714 × 0·3282 = 3184 } 3115 — 3193 ÷ 1·
467·15 + 2·0 = 48·15 / 0·004972 = 9702 × 0·3170 = 3076
467·055 + 2·0 = 48·06 / 0·004972 = 9664 × 0·3248 = 3189 } 3135
467·165 + 2·0 = 48·165 / 0·004972 = 9667 × 0·3231 = 3130
498
31248

The mean corrected number of amp. hours by standard meter = 3189 gms + 1·2266 = 2666
" " " " " " by left hand strip (Upper) = 2554 × $\frac{1·01}{1·0039}$ = 2568 } 2591
" " " " " " Lower = 2592 × $\frac{1·0039}{1·01}$ = 2623
The mean cor. of both etc has thus been increased in ratio $\frac{2591}{2666}$ = 1·003

Test of Resistance of Meter Bottles.

The test recorded on p. 48 was repeated under more favourable conditions and with less liability to error.

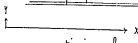
The hot box was maintained at 87°F 30°C and the cold box at 39°F = 4°C. The test commenced at noon on the 23rd Apr. and continued without interruption until 9 am on the 26th (69 hours). The thermostats worked effectively. The current was about $\frac{0.7}{220}$ = 3.3 ampe. (One KHO cell, and 200 v).

Plate	Diff (1-19) 23.5.90	Condition	Shunt	Temp.	Condition on removal	Difference 26.5.90	Thermofor X2	Assumed Thermofor for W2 &c.	W-w	W-w / w	Res. of Shunt	Res. of bottle
1												
2	0.4825	Not analyzed	∞	30°C	slightly smoky	1.3135	0.8310	0.8295				
3	0.8240	"	∞	30°C	o.k.							
4						0.0040	0.8280					
5	1.8530	"	~~0.978~~ 0.978	30°C.		1.5110	0.3420		0.4875	1.426	0.978	1.395
6												
7	0.9540	"	~~2.996~~ 2.996	4°C		1.3555	0.4015		0.4280	1.066	2.992	3.190
8												
9	0.8825	"	~~2.996~~ 2.996	4°C.	slightly smoky	1.2310	0.3485		0.4810	1.380	~~3.016~~ 3.016	4.156
10												
11		"	~~0.986~~ 0.986	30°C								
12	1.9933					2.3175	0.3242		0.5053	1.559	0.993	
13	0.5135	Fold analyzed	~~0.993~~ 0.993	30°C		0.2000	0.3135		0.5160	1.646	0.983	1.618
14												
15		"	~~2.997~~ 2.997	4°C	heavily lightened	0.5325	0.4699		0.3596	0.7653	2.975	2.277
16	1.00224											
17	1.6510	"	~~2.982~~ 2.982	4°C.		2.0655	0.4145		0.4150	1.001	2.980	2.983
18												
19												
20	0.9407	"	∞	4°C	heavy smut	0.1678	0.7729		0.0566	-		
21												
22	0.2585	Black bottle	~~1.996~~ 1.996	4°C	heavy smut	0.1725	0.0860		0.7435	4.310	3.010	12.94

Synopsis of Results

Nos of bottles	Condition		Smut.	Transfer	Shunt	W-w / w	Res. of bottle	Mean	General Mean	Temp			
5-6	Hot Box	Hot	--	0.3420	0.978	1.426	1.395	1.472	1.520	30°			
11-12			—	0.3242	0.993	1.559	1.548						
13-14		Cold	—	0.3135	0.983	1.646	1.618	1.618					
7-8	Cool Box	Hot	—	0.4015	~~2.996~~ 2.992	1.066	~~2.190~~ 3.190	3.673	3.151	4°			
9-10			slight	0.3242	3.0120	1.380	4.156						
15-16		Cold	lightened by smut	0.4699	2.975	0.7653	2.277	2.630					
17-18			"	0.4145	2.980	1.001	2.983						

Elementary Mathematical Theory of relation of permeability of iron to direction of magnetisation.



Let a magnetising force H act in the direction x upon a piece of iron and let this induce a magnetisation I in the same direction, of amount expressed by the equation $I = f(H)$

Then any small increment dH will produce in I an increment

$$dI = d\frac{f(H)}{dH}.dH.$$

The induction $\mathcal{B}$ through the iron will be in the first instance

$$\mathcal{B} = H + 4\pi f(H)$$

and in the second

$$\mathcal{B} + d\mathcal{B} = H + dH + 4\pi\left\{f(H) + d\frac{f(H)}{dH}.dH\right\}$$

and since μ_x is measured by $\frac{d\mathcal{B}}{dH}$

$$\mu_x = \frac{d\mathcal{B}}{dH} = \frac{dH + 4\pi\, d\frac{f(H)}{dH}.dH}{dH} = 1 + 4\pi\, d\frac{f(H)}{dH}.$$

$$= 1 + 4\pi f'(H).$$

Next suppose that a small force h is added in direction y. The resultant will be $\sqrt{(H^2+h^2)} = H + \delta H$ say. The magnetisation in the resultant direction is $I + dI = f(H) + d\frac{f(H)}{dH}.\delta H$ as before, and the resolved part of this in the direction of y is

$$\frac{h}{\sqrt{(H^2+h^2)}}\left\{f(H) + d\frac{f(H)}{dH}\delta H\right\}$$

or $\frac{h}{H}f(H)$ very nearly since h & δH are small.

The induction in direction of y is therefore

$$\mathcal{B}_y = h + 4\pi\frac{h}{H}f(H)$$

$$\text{and } \mu_y = \frac{d\mathcal{B}_y}{dh} = 1 + \frac{4\pi f(H)}{H}$$

Consequently $\mu_x - 1$ should be proportional to $f'(H)$ or $\frac{dI}{dH}$

and $\mu_y - 1$ - - - - $\frac{f(H)}{H}$, or $\frac{I}{H}$, or κ

Also since $I = \frac{(\mu-1)H}{4\pi}$ where μ is a function of H

$$\frac{dI}{dH} = \frac{\mu-1}{4\pi} + \frac{H}{4\pi}\frac{d\mu}{dH}$$

$$\therefore \frac{dI}{dH} - \frac{I}{H} = \frac{H}{4\pi}\frac{d\mu}{dH}$$

So that $\mu_x > \mu_y$ while μ is increasing

$\mu_x = \mu_y$ when μ is a maximum

and $\mu_x < \mu_y$ while μ is diminishing

This relation appears to be fairly well satisfied by the experimental results.

Back of Cylinder I
Time 9.24
Boiler P. 65 lbs.
Mean Imp P 45
Spring 40
Planimeter area 2.185 □"
M.I.P. 20.34 lbs.
[illegible] mm

Back of Cylinder II
Time 9.19
Boiler P. 7 lbs
Mean Imp P 47
Spring 40
Planimeter area 2.17 □"
M.I.P. 20.2 lbs
[illegible] mm

Front of Cylinder III
Time 9.23
Boiler P. 25 lbs
Mean I.P. 51
Spring 30
Planimeter area 2.61 □"
M.I.P. 18.66 lbs
51.5 mm

Front of Cylinder IV
Time 9.15
Boiler P. 67 lbs
Mean I.P. 52.5
Spring 30
Planimeter area 2.44 □"
M.I.P. 18.9 lbs
51.5 mm

Resumé of Results on Copper Matte

No. of Obs.	Date of Trial	Page of Record Book	Amp: hrs passed thro bath	Regulo	Amp: hrs per ton of matte	Weights attached	Mean
1	Mar 19. 1890	12	247	242	684,000	(1)	684,000
2	" 21	13	12	246	492,000	(2)	984,000
3	" "	"	"	313.5	627,000	(1)	627,000
4	" 30th	28	580	216	432,000	(3)	1296,000
5	Apr. 23rd	47.51	600	192	384,000	(3)	1152,000
						10	4743,000
							Mean 474,300

Activity of Brown Engine at Phonograph Works.

29th April 1890.

Engine driving all the machinery and a #10 Dynamo supplying power to the other buildings. The Doll Factory motor however operated from Laboratory direct.

No. of Obs.	Time	Boiler P. lbs	Revs. per min	Diagram	Spring.	Mean I.P. lbs.	Planimeter area	Cut off.	H.P.	Knots.	M.I.P. lbs.	Cylinder
1	9.10	67	51.5	V	40	48	2.25 □"	1.738 1.247	356	26.6	20.5	Back
2	9.15	67	"	III	30	52.5	2.64	1.695 1.265	32.03	23.9	18.9	Front
3	9.16	"	"	II	40	47	2.17	1.738 1.247	35.1	26.2	20.2	Back
4	9.23	65	"	III	30	51	2.61	1.695 1.265	31.62	23.6	18.66	Front
5	9.24	"	"	I	40	45	2.185	1.738 1.247	35.25	26.3	20.28	Back
									134.00	100.0		
									67.00	50.0		

Measurement of Platinoid Governor Shunt Wire for Phonograph Factory 29th April 1890.

The resistance of this shunt wire has always been 1 ω.
A sample of wire was tested. Diam 0.0185". Length 17½" = 1 ω.
27" of this wire is little more than 1.5 ω.

Smutting tests of meter bottles.

Four bottles standard new type made up two with hot and two with cold amalgam. Temp. of room about 18° C. Circuit closed at 17 o'clock I. V. 90. Smut discovered 8 o'clock I. V. 90. or after 15 hours. Current 16 milliamperes or approximately double full load. No appreciable difference in behavior between the hot and cold amalgamations. It is probable that smutting commenced after 12 hours, and commenced at the edges of the plates.

Ten meter bottles in proper condition with new plates were emptied into a cylinder. The total volume amounted to 314.8 c.c. or 35 c.c. per bottle.

Smutting of the plates in the 8 mamp + 12 mamp bottles commenced to be visible after about 9 hours in each case.

Electro-Deposition of Matte.

The last experiment on deposition of matte recorded on page 47 was continued with about 8 amperes of current until the 6th May. The matte plate was then weighed and the results compared.

Loss of Copper bath anode 244 g) = 680.4
Gain - - - cathode 243 g. = 673.4 } Mean 676.9
Loss of Matte 3 lbs = 1360.8
Ratio of matte loss to copper loss 2.01

384 1 amp. hr. dissolves 1 lb. of copper
1 g. - - - 1 - matte
384,000 - - - 1 ton of matte.

46·46 (1 + 0·00388 × 11) 46·46 (1 − 0·00388 × 11) 46·46 (1 + 0·00 0088)

46·46 × 0·99 8728 = 46·29 46·46 × 0·99 8728 = 46·41 46·46 × 1·03 445

As shown at the foot of the opposite page, the best mean value for the bottle resistance is

1·80 @ 30°C
2·5 @ 24°C
4·10 @ 10°C

The resistance of the steel being 46·46 ω @ 21·1°C. = 46·29 ω @ 20°C
46·46 ω @ 10°C
48·07 ω @ 30°C

@ 10°C, the bottle circuit is 48·58 ω 0·47 in defect or nearly 1%
@ 30°C . . . 49·87 ω 0·9 in excess or nearly 2%
@ 21·1°C . . . 48·96 ω

x (0·95725) = 1·6 x × 0·0345 = 0·7
0·04231 x = 1·6 x = 20·3 Ω
x = 37·9 Ω } 9·36 9·5 26·16
46·46 ω 46·46

Test of the Resistance of Meter Bottles.

The test recorded on p. 49 was repeated. The hot box temperature could not be sustained however, and its probable mean temperature was about 21°C. The cold box temperature was steady at 4°. The current was about 3·5 m amps through series. Amalgam all cold. Fuels Laboratory solution 3% zinc.

Day	Bottle	Shunt	Temp.	Condition on removal	Difference	Difference	Transfer ×2	Assumed Transfer for bottle	W − w	W/w	Res. of bottle	(W − w)/w	Mean res.
1		#1.2-9.40	Bot 10°C	OK.	1·3245	2·1160	0·7935		0·5900	1·345	2·487	0·7495	
2												0·7495	
3		#2-2.97	"	"	0·4885	1·2615	0·7730		0·6105	1·266	2·364	0·7698	
4													
5		#3-2.98	"	"	0·3475	1·2195	0·7720		0·6115	1·263	2·360	0·7919	2·359 @ 4°?
6													
7		#4-3.00	"	"	0·3460	1·1070	0·7610		0·6225	1·222	2·265	0·8183	
8													
9		#5-2.97	"	"	0·3015	1·0790	0·7775		0·6060	1·283	2·319	0·7794	
10													
11		#7-0.94	Hot 20°?	"	0·2325	0·7340	0·5015		0·8820	0·5685	1·750	1·759	
12													
13		#8-0.98	"	"	0·6775	1·1435	0·4660		0·9175	0·5079	1·936	1·969	
14													
15		#9-1.02	"	"	0·4175	0·7910	0·3735		1·0100	?	-	—	1·887 @ 24°C ?
16													
17		#10-0.98	"	"	0·3220	0·7860	0·4640		0·9195	0·5046	1·968	1·982	
18													
19	∞		"	"	0·0420	1·4260	1·3840						
20													
21	∞		"	"	0·2230	1·6010	1·3780	1·3835					
22													
23	∞		Bot. 10°C	Bottle Shunted	1·3205	0·0660	1·3885						
24													

Collection of Results on Bottle Resistance.

(1)	Mary 6½ 1889	Record Book III p. 107	Calorimetry Test	Bottle after use =	1·04 ω @ 32°C	3·76 @ 4·5°C		
(2)	" 14th "	" " " 109	" "	" " "	0·72 @ 34·5°C	3·16 @ 10·3°C		
(3)	" 22nd "	" " " 124	" "	" " temp	1·27 @ 31·4	7·87 @ 6·5°C		
(4)	June 8th "	" " " 138	" "	" " temp	1·46 @ 32·2	5·07 @ 7·7		
(5)	" 11th "	" " "	Pattison Test	bottle ground	2·52 ω @ 20°C.			
(6)	" 29th "	" " "	Laboratory	" "	2·635 @ 23·3°C.			
(7)	" " "	" " "	"	" "	1·74 ω @ 32·2	4·07 @ 8·3	2·45 ω	
(8)	April 18th 1890	" " III " 49	"	" " temp bottle shunted	1·52 @ 30°	3·15 @ 4°		
(9)	" 30th "	" " " 52	"	" "	2·36 @ 4°C.			

Best results are No. 4 1·46 ω @ 32·2 5·07 @ 7·7 = 3·61 ω for 24·5° = 2·85
" 7 1·74 " " 4·07 @ 8·3 = 2·33 ω " 23·9° = 1·95
" 8 1·52 " 30° 3·15 @ 4° = 1·73 ω " 26° = 1·67
0·66

Referring these to 30°, 10°. No 4 = 1·69 @ 30° 4·83 @ 10°C Weight (3)
7 1·97 " " 3·89 " " (3)
8 1·52 " " 2·53 " " (1)

5·07 " 30° 14·49
5·91 11·69
1·52 2·53
12·50 28·49
1·79 4·10

Tests to ascertain the amount of local action in the Edison-Lalande battery. 5th May 1890.

Weights were taken of 15 zincs of the small telephone type. All these zincs were put into cells, and the cells left idle on open circuit. The object of the test was to see how the method of uniting the zincs and coppers affected the local action in the cell. Three Nos. 1 + 3 were connected with the usual silver-latex rubber connector. Three others Nos. 5 & 6 were connected with rubber connector of the smooth metal pattern from Bergmann & Co. Three nos 2 + 4 were connected above by V washers of rubber pointing downwards, Two, nos 7 + 8 were not connected at all but were kept apart widely from the coppers, and the remaining four nos 10. 12. 14. 15 were cast in one bottle touching each other without any coppers.

Zinc No.	Weight 5.V.90	Connection	Weight 8.V.90	Loss	Weight 11.V.90	Loss	Weight 19.V.90	Weight 26.V.90	Loss				
1	32.685	Ordinary	32.525	0.160	32.330	0.355		31.910	0.775				
2	34.865	Polished ▼	34.815	0.050	33.910	0.955		26.495	8.370				
3	32.960	Ordinary	32.920	0.040	32.865	0.095		15.005	17.955				
4	34.480	Polished ▼	34.435	0.045	34.345	0.135		broken 30.030	30.				
5	31.390	Polished ●	31.355	0.035	31.300	0.090		30.030	1.360				
6	31.720	Polished ●	31.670	0.050	31.570	0.150		23.840	7.920				
7	28.185	no connection	28.005	0.180	25.180	3.005	24.737	22.440	4.745				
8	32.695	" "	32.670	0.025	32.625	0.070	Box of 24.3 removed the Nos + left in box in solution of Nitric Acid	32.260	0.435				
9	31.320	Polished ▲	31.270	0.050	30.910	0.410		29.080	2.240				
10	35.270	Alone	35.245	0.025	35.210	0.060		35.075	0.195				
11	29.085												
12	34.090	Alone	34.055	0.035	34.055	0.035		33.980	0.110				
13	33.490		33.485	0.005	33.470	0.020		33.385	0.105				
14	31.460	Alone	31.435	0.025	31.420	0.040		31.230	0.230				
15	33.185	Alone											
16													

To check the experiment in progress as recorded on p. 40. concerning the loss by local action of plates in Nitric Acid, four cells were made up just under practical working conditions, but left on open circuit, with the zincs weighed as follows:-

Zinc No.	Weight 6.8.90	Weight Wt. 6.V.90	Weight Wt. 10.V.90	Weight Wt. 11.V.90	Weight Wt. 28.V.90								
10	5142.5	3333	337.1	330.5	32.9								
11	5187.5	336.2	340.3	335.7	331.2								
12	5052.5	327.4	324.9	299.6	301.5								
13	5012.5	324.9	330.6	328.0	327								
14	12280	12,495	12545	12472	12498.8								
15	12031	12,335	12405	12332	12398								
16	12052	12,352	12405	12356	12401.3								
17	12962	12,290	12314	12294	12348								
	Mean	330.5	328.2	323.14	322.2								
	"	12364.8	12402.14	12364.14	12400.9								

11g 333
" 375.
" 240
" 200
24h 12g 34
11g 284
11g 250
11g 150.

Test commenced 6th May. Copper oxide plates in each jar.
Sp. g. of solution 1.280

Meteorological Record.

Date	Time	Barometer readings Inches.	Bend.	Temp.	Degrees of F.C.	Thermometer readings Max.	Min.	Dry	Wet	Rainfall in Inches.	Wind	Remarks.
May 3	Noon	29.562	75.87	67°	29.736	62°	39°	60°			SE	Fair
4		29.551	75.11	63°	29.466	63	42	60				Overcast
5		29.347	74.60	66°	29.267	74	58	73		.34	S	Raining
6		29.489	74.67	66°	29.341	75	60	59	58	.34	N.W.	Rainy
7		29.125	75.60	61°	29.636	65	45	59	51	.06	W	Overcast Raing.
8		29.724	75.78	69°	29.618	63	44	46	44	.08	N.W.	Raining.
9		29.571	75.88	65°	29.112	68	44	60	63		S	Fair.
10		29.677	75.39	63°	29.394	70	56	67	62		N	Overcast
11		29.567	75.87	62°	29.771	72	50	57	52	.065	W.	Raining.
12		29.869	75.82	62°	29.259	71	45	61	54		SE	Fair.
13		29.617	75.23	63°	29.534	72	46	63	59		E	Overcast
14		29.529	75.02	69°	29.419	72	59	75	69	.415	S	Overcast, Fair
15		29.435	74.20	60°	29.527	78	63	65	63	.51	SW.	Raining.
16		29.645	75.31	60°	29.537	85	56	73	65	.01	SW.	Overcast. Fair
17		29.655	75.33	63°	29.562	78°	44°	63°	55°	.17	S	Overcast
18		29.663	75.57	62°	29.733	74°	43°	61°	55°			Fair.
19		29.673	75.43	63°	29.400	70°	50°	60°	65°		E	Overcast
20		29.323	74.64	66°	29.291	71°	52°	60°	57°	.43	N.W.	Raining
21		29.771	76.10	62°	29.581	70°	43°	61°	56°	.04	N	Fair.
22		29.770	76.27	63°	29.815	69°	43°	61°	56°		N.E	Fair.
23		29.853	75.91	62	29.783	69	42	60	56		N.W.	Fair.
24		29.815	75.70	64°	29.728	70	56	68	64		N.E	Fair Overcast
25												
26		29.269	75.83	67°	29.162	72°	52°	50°	50°	.24	E	Raining
27		29.563	75.10	69°	29.467	71	59	71	67	.9	NW	Overcast
28		29.663	75.39	65°	29.568	76	53	63	59		W	Fair
29		29.777	75.64	67°	29.672	78	53	68	62		N.W.	Fair
30		29.696	75.43	67°	29.590	77°	52°	67°	64°		E	Fair Overcast
31		29.682	75.18	68°	29.474	80°	50°	72°	66°		W.	Fair
June 1		29.703	75.46	71°	29.531	88°	53°	76°	70°			Fair
2		29.717	75.74	73°	29.656	80°	55°	76°	67°		N.W.	Fair
3		29.725	76.02	70°	29.811	81°	58°	72°	66°		E.	Overcast
4												
5												
6		29.685	75.41	78	29.547	80°	63°	80°	73	.375	NE	Fair
7		29.641	75.30	76°	29.515	83	62°	77°	65°	.33	SW.	Fair Overcast
8												
9		30.087	76.23	72°	29.819	82°	54°	75°	70°		S.	Fair
10												
11												
12		29.645	75.32	76°	29.523	86°	56°	75°	72°	.80	E	Raining.
13		29.665	75.35	68°	29.557	77°	55°	66°	65°	.19	N	Overcast
14		29.667	75.37	70	29.555	79	62	68	67	.38	N	Overcast
15		29.869	75.86	70	29.765	75	62	67	65	.25		Rain Overcast
16												
17		29.891	75.85	67°	29.760	78	52	71	69		SE	Overcast
18		29.644	75.27	70	29.530	86	53	83	80		S	Overcast
19		29.703	75.91	77°	29.568	87°	53°	79°	74°		N.W.	Fair
20		29.935	76.04	76°	29.801	83°	52°	71°	66		N	Fair
21		29.535	75.53	70°	29.739	73°	55°	63°	62°	.10	SE	Overcast Rain
22		29.701	75.45	67°	29.674	73°	56°	71	67	1.01	N.W.	Overcast Fair
23		29.567	75.84	68°	29.759	78°	62°	67°	65°		N	Overcast
24		29.805	75.71	72°	29.683	83	65	79	73	.015	N.W.	Fair.
25		29.577	75.14	84	29.471	87	73	83	79		N.W	Fair
26		29.637	75.57	80°	29.493	90°	68°	80°	74°		N.W.	Fair
27		29.688	75.31	75°	29.518	83°	62°	72°	68°		N.W.	Fair
28		29.609	75.21	76°	29.483	81°	62°	76°	73°		SW.	Fair Overcast
29		29.644	75.21	77°		89	65	79	74		N.	
30		29.729	75.52	77°	29.491	93°	67°	82°	77°		N.W.	Fair
July 1		29.761	75.64	80°	29.617	93°	63°	87°	77°		SE	Fair Overcast
2		29.679	75.44	75°	29.570	89	66	74	71	.35	SE	Overcast Raing
3												
4		29.534	75.15	73		79	70	77	75	.37	S.W.	Rain

Meter Experiment 8th May. 1890

Since the electro chemical equivalent of Bismuth is 2·184 mgms, and that of Zinc is 0·337, it follows that Bismuth would be six times as valuable as zinc in a meter designed to absorb very little power. Made up solutions of 5 grammes of Bismuth in Hydrochloric sulphate, oxychloride, iodide, nitrate, subnitrate, oxyhydrate, ~~and~~ subcarbonate and phosphate. All these salts appear to be practically insoluble in water. Tried the nitrate with nitric acid. This rendered it soluble but the strength of acid which did so attacked free bismuth plunged in it. Tried the sulphate in sulphuric acid with more success. This dissolved the salt and at the same time did not apparently attack the plate. The resistance of a little cell made up in this way with small pieces of bismuth, not exposing more than 0.5 sq. cm. each was 10 ω f.e. 50 ~ 12 ~~volts~~ ~~in~~ 100 ohms or 3 milliampere = 40 × 0·003 = 0.12 volt counter e.m.f. This is comparatively good.

Test of the Wint Lightning Protector. 9th May. 1890

This apparatus consists of a grounded base plate and frame holding a vertical column of 20 copper washers separated by disks of mica. Each washer is 0·3 thick and 5. in diam. The mica disks are about 0·08 thick. An insulated wire runs through these washers to the top one with which it makes permanent connection. The effect of the plates is to permit the discharge of high tensions without allowing the municipal current to follow it.

Two protectors were received for test. Number one was tested with the municipal dynamo for simple resistance to disruption. With about 900 volts the machine could only be got to discharge at the last plate. With six leyden jars each exposing about 1·5 sq. ft. or nearly 10 sq. ft. of glass in all and the Holtz machine, a spark of about ¾" could be obtained, very dense and with a loud report. With 600 volts at the dynamo, the leyden jar discharge did not precipitate the discharge of the machine over 2 plates but 1000 volts were precipitated. With the leyden jars, the discharge would take place across all twenty plates.

Number two was tested in the same way. The machine would not discharge across three plates until the PD was raised to about 1000 volts.

Since a 300 amp. hr. cell holds 0.7 gallon of solution

burns	3·6 lbs of zinc	per cell
reduces	1 - -	CuO - -
consumes	2 - -	$NaHO$ - -

the 3000 amp. hr. cell will need 7 gallons of solution

36 lbs. of zinc

10 - - CuO

20 - - $NaHO$

Suppose that we take 7 gallons of solution

46 lbs of zinc

10 - - CuO

20 - - $NaHO$.

1 gallon U.S. = 270 c.i. 1890 c.i. required

If 12" in diam. internally - 113 sq. in. area

= 16.7" high.

Say 12" diam. and 20" high.

Two zinc plates 9" × 19" each ·225 lbs wt

171 sq. in. = 42 lbs. if 1" thick

Four zinc plates 9" × 19" × ½"

In the 300 amp. hr. cell a CuO plate 4·75" × 4" × 0.375" = 7.125 cu. in. weighs 1 lb. 19 sq. in.

Two plates 15" high × 6⅓" wide 95 sq. in. each 5 lbs.

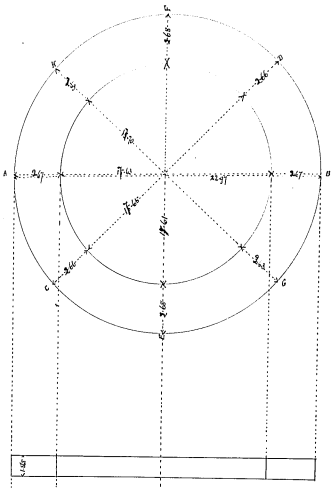
The 900 amp. hr. cell holds 2·5 gallons, without allowance for lift out. 11½" high to shoulder. 7½" diam.

Comparison between the Cost of Operating a Mason-Reed Battery, and an Edison-Lalande Battery, for current, and for power.

		Mason.	Edison-Lalande
Dimensions	Area occupied per cell	100 sq. in.	244 sq. in
	Height - - -	12"	12"
	Weight charged - -	60 lbs.	18½ lbs.
	Floor space per actually occupied H.P. (@ 4 amperes)	70 sq. ft	37 sq. ft.
	Weight per H.P. (@ 4 amperes)	6000 lbs.	5550 lbs.
	Cost to purchaser per cell	$ 7.20	$ 2.25
	- - - per H.P.	$ 720	$ 675
	Ampère hours at 4 amperes	180	290
	Initial E.M.F. per cell	2·2 volts	0·8 volt
	Mean - - -	2·0 -	0·7 -
	Mean int. res. - -	0·08 ohms	0·03 ohms
	Mean P.D. - -	1·45 volts	0·57 volt.
	Mean ch. energy per cell @ 4·5	7·5 Watts.	2·5 Watts
	Mean cells per H.P. est.	100	300.
	Zinc consumed per 1000 H.P. hr.	12.13 lbs.	36.40 lbs.
	Cost of Zinc consumed per 1000 H.P. hr.	$ 97	$ 291
	Charge of Depolarizing fluid p.c. (1820)	½ gallon	
	Depolarizing fluid per amp. hr. per cell	0.003 gallon.	
	- - - H.P. hr.	0.8 -	
	- - - 1000 H.P. hr.	800	
	Depolarizing consumed of Depolarizer per gallon	$ 0.25	
	- - - - - H.P. hr.		$ 0.075
	- - - - - 1000 H.P. hr.		$ 75
	Sulphuric acid per amp. hr. per cell	0·008 lb.	
	- - - H.P. hr.	1 lb.	$ 0.0125
	- - - 1000 H.P. hr.	1000 lbs. @ $0.0125	$ 12.50
	Copper-oxide consumed per amp. hr. per cell	0·0033 lbs.	
	- - - - H.P. -	1 lb.	
	- - - - 1000 H.P. -	1000 lbs.	
	Cost of copper-oxide per 1000 H.P. hr. allowing for copper as 20 cts. lb	$ 200	
	Caustic Soda consumed per amp. hr. per cell	0·008 lbs	
	- - - - H.P. hr.	2 lbs.	
	- - - - 1000 H.P. hrs.	2000 lbs.	
	Cost of caustic soda per 1000 H.P. hrs. @ 8 cts. lb.	$ 160.	

Total cost of Mason cell per 1000 H.P. hrs. $ 187 = $ 0·19 per H.P. hr.

" " " Edison-Lalande - - - - - $ 790 = $ 0·79 per H.P. hr.



$22.96 + 17.65 = 40.61 = 20.303 \times 3.1416 = 62.96 \times \frac{5}{11} = 167.15 \times 1.565 = 261.6$

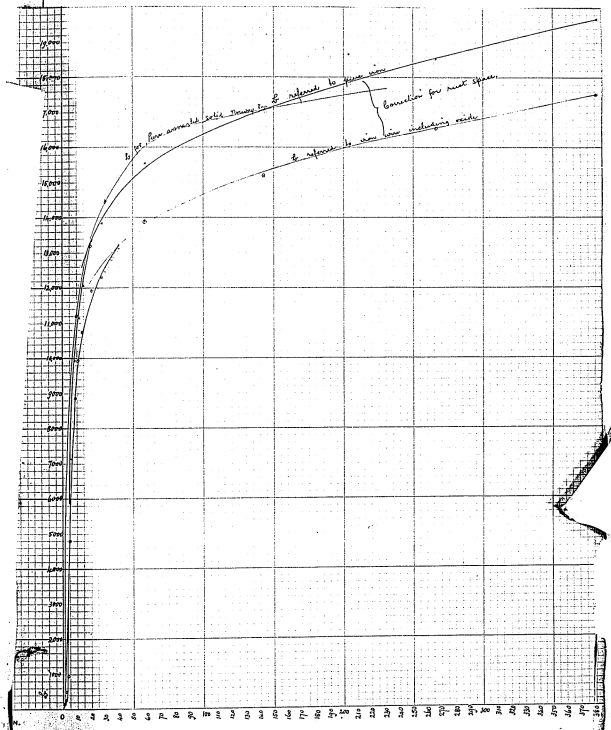
Area of iron + ends $= 11.38 \times 0.018 \times 0.018 \times 6.4516 \times 0.7854 = 2.361$ sq. inch

Source of EMF	Temp	Resds.	EMF at temp	a	No. of turns	Mean Thur	t_m	a per sec
1 Ch.	20.5°C	1 ρ 1×10^{-15}	1.4322×10^{-3}	1.4322×10^{-3}	13	121.5	± 0.1	1.179×10^{-3}
1 Ch.	20°C	1 ρ	1.4325	1.4325	14	124.7	± 0.15	1.149×10^{-3}

$\rho = d \times 1.179 \times 10^{-3} \times 7 \times 10^{3} \div 10^{2} = dr \times 1.179 \times \frac{7}{100}$

$+ \; d \times 1.149 \times 10^{-3} \times 7 \times 10^{3} \div 10^{2} = dr \times 1.149 \times \frac{7}{100}$

On dropping these pieces of rusted iron the iron diam. were found to average 0.017" and over rust 0.018 so the area has been reduced in ratio 289 : 324 ∴ the observed values of L may be multiplied by $\frac{324}{289} = 1.121$


Is the flow assumed to be stream line to be referred to free surface
Correction for mean spheres
Is referred to mean line indicating reality

H C.G.S.U.

Magnetic Permeability of an Iron Wire Ring from Schenectady) compressed hydraulically)

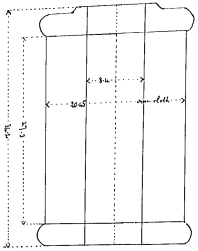
This ring was received from Schenectady on the evening of the 11th May. It was made up of 11.38 turns of #26 BWG 0.018" 0.045cm. oxydized superficially. Its breadth was about 45 wire (per layer) and its depth about 32. This would represent 16.9 wire per cm. in breadth and 20.125 wire per cm. in depth.
0.059 cm. each — 0.0749 cm. each

Ext. Diam.	Mean Ext. Diam.	Probable error.	Int. Diam.	Mean Int. Diam.	Probable error.	Depth	Mean Depth.	Probable error.	Surface area.	Volume.	Cross section Mean.	Weight in air.	Sp. g.
22.97			17.63			1.52							
						1.56							
22.96						1.52							
	22.96	±0.003	17.65	17.65	±0.01	1.59	1.565	±0.011	167.4	2626	4.155	1189.6	4.5
22.97	See Index 22.89					1.60							
			17.61	See Index 16.95		1.60	See Index 1.495						
				17.72		1.60				2433	3.865 allowing for Lap.		4.5
22.95						1.53							
			17.70										

Mean Diam. 20.205 Mean Circumference 62.96 Sp.g. refund to the wire 8.00.

50 turns of #25 BWG. copper wire were laged on in one layer upon the ring over tape. Above this 231 turns of 0.072" covered to 0.086" in one layer, there 231 similar turns in a second layer, and 227 similar turns again in a third layer. The total no. of turns being 689, or 10.94 per cm.
13.721

Flux in Webers	Sol. Cotan. Deflection	Time of Dep.	Current amperes	H	No. of Shunts.	Mean Throw	Probable error.	φ (6.199)	Resist. in G. coil.	L refund to Ferrite.	μ.	L refund to the wire only.
21+50	6°.35'	0.1154	0.087	1.194	5	5.9	±0.1	365.3	5,250	155		174
31+50	9°.30'	0.1673	0.126	1.729	6	6.9	±0.2	551	"	233		261
21+110	13°.15'	0.2355	0.1775	2.436	4	17.1	±0.4	1059	"	448.5		503
21+50	15°.15'	0.2726	0.2055	2.820	7	22.7	±0.5	1405	"	595		667
21	16°.15'	0.2915	0.2198	3.016	8	36.2	±0.6	2241	"	949.2		1064
	17°.25'	0.3201	0.2414	3.313	4	50.7	±0.5	3139	"	1330.		1491
	19°.15'	0.3492	0.2633	3.614	5	72.8	±0.4	4507	"	1909		2140
	21°.0	0.3839	0.2895	3.973	5	103.4	±0.7	6400	"	2711		3039
	22°.40'	0.4176 0.063	0.3144 0.3183	4.321 4.367	6	134.8	±0.7	8344	"	3534		3969
		0.070	0.3536	4.854	6	183.3	±1.4	11350	"	4808		5390
41+110	6°.15'	0.1695	0.073	1.139	4	9.3	±0.8	561	"	238		267
31+110	9°.5'	0.1599	0.121	1.661	5	14.4	±0.7	869	"	368		412
21+110	12°.0	0.2493	0.188	2.580	6	37.3	±0.7	2250	"	953		1068
21	17°.30	0.3123 0.0149	0.2371 0.2478	3.259 3.397	5	76.7	±0.6	4627	"	1960		2197
11+{1/2}		0.053	0.268	3.678	6	99.7	±0.9	6015	"	2546		2856
11+110		0.061	0.308	4.227	5	138.8	±0.7	8372	"	3547		3976
11+40		0.078	0.394	5.407	5	207.2	±0.8	12,500	"	5295		5935
11+10		0.090	0.455	6.245	5	244.0 244.0	±1.6 ±1.0	14,800 15,300	3,250	6374		7144
{1/2}+70		0.110	0.556	7.632	6	52.5	±0.4	18,250	"	7730		8664
{1/2}+29		0.134	0.678	9.306	6	60.2	±0.1	20,930	"	8866		9940
{1/2}+19		0.170	0.8565	11.780	5	67.5	±0.4	23,460	"	9936		11,140
{1/2}		0.205	1.035	14.21	6	73.1	±0.3	25,410	"	10,760		12,060
72		0.302	1.526	20.94	5	81	±1.1	28,150	"	11,920		13,360
		0.441	2.025	27.79	4	96 162.3	±1.1	29,890 28,370	7,250 16,250	12,330		13,820
		0.855	4.32	59.29	5	187.2	±1.5	32,790	"	13,890		15,570
		2.05	10.35	142.1	4	204.8	±2.4	35,880	"	15,200		17,040
		3.84	19.4	266.3	4	223	±0.5	39,070	"	16,550		18,550
		5.60	27.78	381.3	3	236.3	±0.7	41,390	"	17,530		19,650



Section of coil 1/10

Weight of coil complete 11 kg.

Inductance of the large Secondary Coil of the Queen Ruhmkorff apparatus.

16th May 1890.

This coil on a wooden frame is separate and lifts off the machine. With a view to its employment in radiant experiments, measured its inductance as follows:-

T.B.	Ratio of Bridge.	Corrected Ratio	Res. for Balance	Corrected L T.B.	Temp. of coil.	Capacity for 1 mf.	Inductance Standard	Time Const. corrected	Time Const. of coil to 0°C.				
22·3	10,000 / 10,000	9.9,120 / 10,000	15,910	20·1 C.	20·4°C	0·701	1095	8,8070	15,666	see also Book III p. 15.			

The total weight is 24·½ lb. Supposing that 2D of this is wire, the res. per lb is 780 ω. This means either #33 BWG 0·008" 832 ω per lb. or #32 B.S. 0·007 95" ·853 ω per lb. These have about 6·16 ft per ohm. or 15600 × 6·16 = 96,120 feet in all. The mean diam is 14·42 cm = $\frac{14 \cdot 42}{30 \cdot 48} \times 3 \cdot 14 = 1 \cdot 486'$ per turn, there will thus be some 64,700. turns of wire.

Experiments with a Cautery Battery of 10 cells.

16th May 1890.

Three cauteries were tested. They were received from Mr Kelly as samples of the requirements to be fulfilled by the battery. A hard rubber handle or stock holds each cautery in a pair of small screw-side terminals. The connections from the wires run through the handle which has a little connecting key at the side for closing the circuit by the finger, and terminate in two large conical nickel plated studs for insertion in the main leads.

The wire cautery consists of a loop of platinum wire 0·017" (0·043) in diam which passes through two copper tubes or hollow guide wires locked together. These tubes enlarge in diameter from the cautery (0·085") up to the clamping end (0·115"). The platinum wire runs entirely through these tubes and is bound round the axis of a little hard rubber roller held by two nickel plated arms about 2·5 long pivoted into the handle. The thumb of the operator can thus diminish the length of the loop by drawing the roller and its attached wire through the tubes. The loop can be thus reduced from 20 to 2 cms.

The knife cautery consists of a pair of stout stems terminating in a little loop of flattened platinum wire. The blade is 0·025 ω thick and about 0·1 cm. wide ⊕ shape. The effective length being about 2 cms.

No. of Exp.	Length of Pt. cautery	Condition	Colour	Current	PD. on Cautery	Res. of cautery	Res. per cm.	Length of wire in cell.	res. of wire	Nat. cells
1	19	Glowing red	1·5	7·6	5·9	0·776 ω	0·0461 ω	40 mm Res. 0·08	0·34	19.
2	10	Nearly white	1·62	8·2	3·65	0·4455 ω	0·0445 ω	65..	0·55	19
3	Knife	- -	3·70	18·7	less than 15	–	–	none	–	10
4	–	Glowing red	3·60	18·2	- - -	-	-	-	-	8
5	Min 15·0	Nearly white	1·46	7·4	4·65	0·628	0·0420 ω			10
6	3	" "	"	"	"			30	0·25 ω	10.
7	none	out of cell	5·60	28·3						10 cells 7·8 ω
	Res. of battery	+ leads	0·275 ω	=		0·25 ω for battery per cell.		+ 0·015 ω for lead		+ 9.

Calibration of Obach Ring Galvanometer

17th May 1889.

At commencement of the measurement, silver plate A was found to be heavier than silver plate B 1.9190 gms.

The current of about 2·6 amperes was passed through the Galvanometer and silver Voltameter in series for 300 seconds.

The mean of all the readings of the galvanometer tangents taken every 15 seconds was 0·5270

The plate A after drying was then found to be heavier than B 0·1028 -

Double transfer 1·8162.

Transfer 0·9081.

In one second the transfer would be 0.0030270 gms.

3·027 ÷ 1·118 = 2·707 amperes = 5.137 for tangent unity

= 0·1947 for 1 ampere.

Experiment on the action of Lithium Chloride upon Uric acid.

20th May 1890.

A few centigrammes of ~~Lithic~~ Uric acid $H_2C_5N_4O_3$ were shaken up with about 2 c.c. of distilled H_2O in a small test tube, and about 2 c.c. of liquid Lithium chloride $LiCl$ added. The two were neutral before mixing, and the mixture was also neutral, showing that no free HCl was found. A rise of temperature was however detected in the test tube.

Repeated the experiment as follows:— about 2 c.c. of $LiCl$ at 19·C was added in a similar test tube to some dry powdered Uric acid. The mixture was stirred by the thermometer bulb and rose to 22·C. very quickly and then slowly fell.

On adding strong HNO_3 to the mixture and evaporating in a sand bath, distinct fumes of ammonia were detected. When however HNO_3 was added to the uric acid alone, no ammonia could be detected by smell and heated. ~~Although~~ a finished deposit turning purple on the addition of KHO showed that there was some small quantity present.

It is therefore probable that the addition of $LiCl$ to uric acid produces some combination but no such reaction as would liberate the chlorine; or form HCl.

Phonographic Battery data

The ordinary 300 amp. hr. New HO battery takes 2750 c.c. of solution Sp. g. 1.25 - 1.26 to fill it, and 2 lbs of NaHO 907 gms.

The rectangular section cell for cautery purposes takes 1500 cc and at the same rate 1 lb. 1 g.

Test of a number of Fuse plug cut outs for Bergmann & Co.

May 23rd 24th

40 cut outs were received from Messrs Bergmann & Co. for test. They were marked from 18 24 30 and 37 ten of each kind. They were not filled with plaster of paris as has hitherto been customary, and the object of the test was to ascertain how far this would be a benefit or disadvantage.

Arranged a plug socket in direct circuit with the Obach Galvanometer, a table wire resistance for controlling the current and the 5 volt main, employing the potentiometer on the socket to measure the p.d. on the tested plug.

No. of Obs.	Number on plug.	Condition	Obach	amperes	P.D. volts	Energy in plug	Res. of plug	Ratio of Res.	Ratio of energy based on 1·00	Diameter of wire
1	37	no plaster	1·17	5·94	0·0744	0·26	0·0074	1·		0·0089"
2			1·68	8·53	0·076		0·0089			
3			2·0	10·15	0·112		0·0110			
4			2·25	11·42	0·104		0·0091			
5		3 used.	2·60	13·20	0·168	2·22	0·0127	1·72	1·81	0·023 cm
1	37	no plaster	1·42	7·20	0·066	0·61	0·00944			
2			2·46	10·97	0·104		0·0095			
3			2·48	12·59	0·196	2·47	0·0156	1·70	2·23	
1	37	no plaster	1·42	7·21	0·062		0·0086			
2			2·48	12·79	0·192	2·46	0·0150	1·74	2·14	
1	37	no plaster	1·47	7·46	0·072		0·0096			
2			2·40	12·18	0·196	2·39	0·0160	1·68	2·3	
1	37	no plaster (paraffin wax used when remoulded)	1·44	7·31	0·060		0·0082			
2			2·56	13·00	0·198	2·59	0·0152		2·17	
1	37	Cup half filled with water	1·40	7·11	0·062		0·0087			
2			2·50	14·21	0·204	2·81	0·0144		2·06	
1	37	cup dry	1·40	7·11	0·058		0·0082			
2			2·58	13·1	0·258	3·38	0·0197		2·81	
1	37	plaster	1·46	7·41	0·060		0·0081			
2			4·40	22·33	0·210	4·68	0·0094		1·33	
1	37		1·53	7·76	0·060		0·0077			
2			4·40	22·33	0·250	5·58	0·0112		1·60	
1	37		1·50	7·61	0·060		0·0079			
2			4·40	22·33	0·200		0·0090			
3			4·70	23·86	0·250	5·97	0·0147		1·50	
1	30	no plaster, dry.	1·52	7·71	0·080		0·0102			0·007"
2			2·22	11·27	0·200	2·25	0·0178			0·0177 cm
1	30	no plaster, dry.	1·54	7·81	0·072		0·0092			
2			2·32	11·78	0·200	2·35	0·0170			
1	30	no plaster, cover removed, dry.	1·50	7·61	0·076		0·010			
2			2·16	10·97	0·200	2·19	0·0182			
1	30	no plaster, cover on, dry.	1·54	7·82	0·080		0·010			
2			1·68	8·53	0·088		0·010			
3			1·86	9·44	0·102		0·0108			
4			1·96	9·95	0·112		0·0113			
5			2·07	10·51	0·122		0·0116			
6			2·16	10·96	0·138		0·0126			
7			2·24	11·37	0·204	2·27	0·0179			

Plate	Number in plating	Condition	Ohms	Amperes	P.D. volts	Energy in plating	Res. of plating	Ratio of res.	Diam. of wire		
1	30	dry, no plate cover on	1·48	7·59	0·066						
2			1·60		0·074						
3			1·82		0·086						
4			1·96		0·098						
5			2·05		0·104						
6			2·126	10·90	0·112						
7			2·200	11·28	0·120						
8			2·240	11·49	0·210	2·41					
1	30	dry, no plate	1·50	7·69	0·074						
2		vertical	1·66		0·086						
3		cover on	1·82		0·096						
4			2·02		0·114						
5			2·12	10·87	0·128						
6			2·16	11·08	0·134						
7			2·20	12·88	0·360	4·64					
1	30	dry, no plates	1·48	7·59	0·100						
2			1·60		0·110						
3			1·72		0·118						
4			1·92		0·126						
5			1·94		0·136						
6			2·02		0·142						
7			2·06		0·144						
8			2·10		0·150						
9			2·16		0·156						
10			2·20	11·30	0·160						
11			2·26	11·60	0·166						
12			2·28	11·70	0·172						
13			2·32	11·90	0·180						
					0·360	3·09					
1	30	dry plates	1·48	7·59	0·074						
2			1·70		0·086						
3			1·78		0·092						
4			1·90		0·100						
5			2·00		0·108						
6			2·18		0·122						
7			2·28		0·130						
8			2·36		0·146						
9			2·56		0·300						
10			2·60	13·34	0·360						
11			2·72	13·95	0·400						
12			2·80	14·36	0·460						
13			2·96	15·18	0·580	8·80					
1	30	plates dry	1·48	7·59	0·070						
2			2·60	13·33	0·310	4·13					
1	30	plates dry	1·48	7·59	0·080						
2			2·40	12·31	0·300	3·69					

Test No.	Number on plug	Condition	Obsch.	Amperes	P.D. Volts	Energy in plug	Res. of plug	Ratio of Res.	Diam. of lead wire	
1	24 lt	Dry no plastic	1·16	5·95	0·106		0·0178			
2			–		0·220					
1	24 lt	no plastic	1·26	6·46	0·118		0·0183			
2			1·40	7·18	0·150					
3			1·50	7·69	0·160	1·23	0·0208			
1	24 lt	no plastic	1·26	6·46	0·122		0·0189			
2			1·38	7·08	0·132					
3			1·44	7·48	0·168					
4			1·46	7·49	0·286	2·14	0·03821			
1	24 lt	n.p. inverted	1·250	6·41	0·134		0·0209			
2			1·410		0·166					
3			1·480		0·354					
4			1·540	7·90	0·388					
5			1·620	8·31	0·428					
6			1·70	8·72	– ?	3·75	0·0491			
1	24 lt	n.p.	1·180	6·05	0·106		0·0175			
2			1·320		0·128					
3			1·520	7·79	0·286					
4			1·620	8·31	0·390					
5			1·620	8·31	0·470	3·90	0·0566			
1	24 lt	n.p.	1·150	5·90	0·106		0·0180			
2			1·380		0·148					
3			1·420	7·28	0·164					
4			1·50	7·69	0·294	2·26	0·03821			
1	24 lt	n.p.	1·19	6·10	0·110		0·0180			
2			1·30		0·130					
3			1·44		0·164					
4			1·46		0·282					
5			1·52		0·334					
6			1·62		0·384					
7			1·66		0·408					
8			1·74	8·92	0·446					
9			1·78	9·13	0·474					
10			1·80	9·23	0·544	5·02	0·0589			
1	24 lt	n.p.	1·16	5·95	Kept on for half an hour.	0·6	plug fused at	some time	in that period	
1	24 lt	plastered	1·08	5·54	0·098		0·0177			
2			1·48		0·170					
3			1·80		0·486					
4			2·00	10·26	0·598					
5			1·94	9·95	0·960	9·6	0·07960			
1	24 lt	plastered	1·16	5·95	0·148		0·025			
2			1·44		0·430					
3			1·72	8·82	0·580					
4			1·80	9·23	0·720	6·7	0·0780			
1	24 lt	plastered	1·22	6·26	0·104		0·0167			
2			1·52	7·79	0·166					
3			1·74	8·92	0·412	3·7	0·04621			
1	18 lt	no plastic	0·55	2·82	0·074		0·02621			
2			0·63		0·088					
3			0·68		0·10					
4			0·75		0·114					
5			0·82		0·134					
6			0·85		0·142					
7			0·90		0·158					
8			0·95		0·180					
9			0·98		0·366					
10			1·03	5·28	0·396					
11			1·12	5·74	0·434					
12			1·15	5·90	0·580	3·4	0·0983			

Number of fuse	Condition	Obach	Amperes	P.D. Volts	Energy in fuse	Res. of fuse	Ratio of Res.	Drop of wire
18	no plaster	0·91	4·67	0·196		0·0420		
		1·00	5·13	0·201	1·03	0·0392		
18	no plaster cap inverted	0·89	4·57	0·1146		0·0319		
		1·0	5·13	0·176				
		1·08	5·54	0·320	1·77	0·0579		
18	no plaster cap not inverted	0·90	4·62	0·190		0·0411		
		1·01	5·18	0·408				
		1·05	5·39	0·500				
		1·10	5·64	0·550	3·1	0·0975		
18	no plaster	0·89	4·57	0·1821		0·0398		
		1·0	5·13	0·426				
		1·05	5·39	0·480				
		1·15	5·90	0·546				
		1·20	6·15	0·602				
		1·31	6·72	0·970	6·5	0·1446		
18	plastered	0·93	4·77	0·170		0·0356		
		1·08	5·54	0·230	1·27	0·0415		
18	plastered	0·91	4·67	0·180		0·0386		
		1·06	5·44	0·486				
		1·14	5·85	0·558				
		1·22	6·26	0·730	4·57	0·117		

Resumé of Results.

Fuse	Res. at normal temp.	Res. at fusing temp.	Mean current fusing (Current wiring 37°) no plaster	Mean energy fusing no plaster	Mean current fusing no plaster	Mean current fusing no plaster	Mean current fusing plaster	Mean current fusing plaster	Mean current fusing plaster	Drop at fusing energy no plaster
37	0·0080	0·0160	12·8 ± 0·1	2·62 watts	–	–	22·8	–	–	0·204 volt
30	0·009	0·018	11·5	2·38 "	11·9	12·9	13·6	–	–	0·207 "
24	0·016	0·035	7·6 ± 0·05	2·20 "	8·5	9·2	10·0	9·2	8·9	0·290 "
18	0·025	0·065	5·5 ± 0·15	1·93 "	5·6	6·7	–	–	5·9	0·350 "

The effect of adding plaster of paris is to retard the fusing and for currents delivered within three minutes to increase the fusing current from 10% for the smallest to 80% for the largest fuse tested.

Removing the cover of a fuse has little effect upon its fusing point.

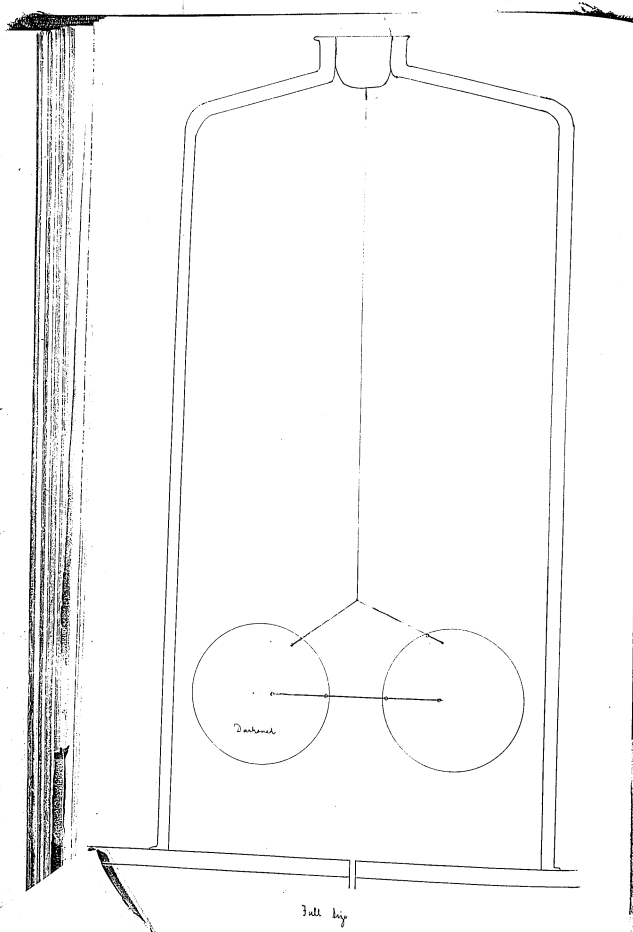
Adding water to a fuse round the wire does not produce a very great effect on the fusing current. In one case had the latter increased 10%.

Inverting a fuse, and particularly setting on its edge increases the fusing current for fuses without plaster. It has little effect on plastered fuses.

The fusing current ~~nearly~~ causes the res. of the fuse to increase between 2 and 3 times.

The drop on a fuse at fusing point is from 0·35 volt for the 18 size to 0·20 volt for the 37 size.

A current long continued will melt a fuse about 20% below the value here given



On the angle of Deflection obtainable from a Disk suspension in vacuo according to Clerk Maxwell's electromagnetic theory of light

Let l be the length of the supporting fibre of single silk.
" r " " mean effective radius of luminous action.
" a " " area on which that force is concentrated.
" θ " " angle of deflection produced in abs. measure
" m " " moment of torsional rigidity of the fibre referred to unit rod.
" f " " pressure due to luminous action in abs. measure.

Then equating moments round the fibre we

$$f a r \cos\theta = \theta m$$

If we keep the limits of deflection small $\cos\theta$ will not differ greatly from 1, and $\theta = \frac{far\,l}{m}$

Assume the following values.

f for sunlight see page 59 Record Book II = ~~70 microdynes~~ page by Maxwell's theory or 3.5×10^{-5} dynes per sq. cm. for powerful sunlight. take $f = 1 \times 10^{-5}$ dynes

$a = 10$ sq. cms.

$r = 10$ cms.

$l = 100$ cms.

$m = 2.5 \times 10^{-3}$ see Phil Mag. Jan. 87 T. Gray.

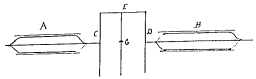
Then $\theta = \frac{10^{-5} \times 10^{4}}{2.5 \times 10^{-3}} = \frac{10^{2}}{2.5} = 40$

or the power exerted by sunlight even 1/10 full intensity should drive the disk with an energy capable of introducing 40 radians or 7 complete turns in the fibre. It is very evident therefore that a disk so suspended should completely test the accuracy of Maxwell's theory.

Required, a mica disk 3.57 cms diam or an arm 10 ~ 1.70 = 8.22 cms long.

The opposite diagram represent the actual arrangement Diameter of vanes 5.1 area 20.42 sq. cms. Radius 3.5 cms effective The fibre is of single silk from the cocoon carefully washed in hot water. Its length is about 18 cms. The suspension is of fine glass rod drawn out in a flame, and secured to the mica vanes with shellac. The left hand vane shewn was darkened by coating with a film of collodion containing lampblack dissolved in ~~methyl~~ ether acetate. The other vane was left uncoated except near the horizontal tie end. The weight of the whole suspension was 0.320 gms. It was secured to the ground glass stopper of a receiver for the air pump.

With air in the receiver, which is secured supported on a pier there seems to be no repose for the suspension which keeps moving slowly in a most erratic manner apparently owing to convection draughts within caused by slight inequalities of temperature.



The two motors will thus be in unstable condition of speed. Whatever changes be made in the strength of their fields will produce no movement of the car and no change in relative velocity if the motors be frictionless, and the only changes possible in their relative velocities will be changes due to friction in the motors.

Let n_1 be the revs. per sec.

Then $n_1 \varphi_1 w + n_2 \varphi_2 w$ + full f emf in armature = E

$n_2 \varphi_2 w + n_1 \varphi_1 w = \frac{E_1}{\rho_a}$ where E_1 = available emf

if $x = 1$ $\quad n_2 = \frac{E_1}{\varphi_2 w(y+1)}$

Whatever value y may have there is some value of x common to both motors at which they will do least work.

Problem. Required the Equation of motion and complete solution of the following case:—

Two similar motors have their armatures A and B in line, and geared together by mitre gearing C D and E. The differential wheel E is fed to revolve on its axis but the axis is on an arm revolving on another G in line with the armature axes. G communicates directly with the car wheel or is itself the car wheel shaft. When A and B are running in opposite directions at the same speed, F spins on its axis with the linear velocity at the pitch line of each but the arm FG is at rest. As now the speed of one motor is increased, that wheel exceeds in velocity and OF revolves thus driving the car. If the armatures are in series, but the fields are separately excited, find the condition of traction.

Let w be the number of wires counted round each armature.

" n_1 n_2 " " revs. of A & B respectively per sec.

" φ_1, φ_2 " " total flux $\times 10^{-8}$ (passing) thro' A & B respectively in C.G.S.V.

" ρ " " resistance of each armature in ohm

" E " " constant E.M.F. maintained on supply.

" m " " moment of inactive effort of the car on FG referred to mitre radius

" μ " " " total friction in each armature shaft assumed uniform

" $n_1 = x\, n_2$

" $\varphi_2 = y\, \varphi_1$

Then " η_1, η_2 be the internal e.m.fs generated by the armatures

$$\eta_1 = \varphi_1 n_1 w \qquad \eta_2 = \varphi_2 n_2 w$$

$$\text{current } c = \frac{E - w(\varphi_1 n_1 + \varphi_2 n_2)}{2\rho} = \frac{E - w\varphi_1 n_2 (x+y)}{2\rho}$$

$$\text{Energy absorbed} = c(\eta_1 + \eta_2) = \frac{w\varphi_1 n_2 (x+y)\{E - w\varphi_1 n_2 (x+y)\}}{2\rho}$$

" counted $= 2\pi\mu n_2 (x+1) + m\pi n_2 (x-1)$

$$= \pi n_2 \{2\pi\mu (x+1) + m(x-1)\}$$

$$\therefore\ w\varphi_1 n_2 (x+y)\{E - w\varphi_1 n_2 (x+y)\} = 2\pi\rho n_2 \{2\mu(x+1) + mx - 1\}$$

This expresses the relation of x to y when the other values are forthcoming.

Let $w\varphi_1 n_2 = J$ $\quad$ To find x

$$J(x+y)\{E - J(x+y)\} = 2\pi\rho n_2 \{2\mu(x+1) + mx - 1\}$$

$$EJ(x+y) - J^2(x+y)^2 =$$

$$x^2 J^2 + x(EJ - 2J^2 y - 4\pi\rho\mu n_2 - 2\pi\rho n_2 m) = -EJy + J^2 y^2 + 2\pi\rho n_2 (2\mu - 1)$$

In this equation first neglect the frictional terms μ for a simpler approximation. Then

$$J^2 x^2 + x(2J^2 y - EJ + 2\pi\rho n_2 m) = EJy - J^2 y^2 + 2\pi\rho n_2$$

Whence $x = \dfrac{EJ - 2J^2 y - 2\pi\rho n_2 m}{2J^2}$

$$\pm \frac{\sqrt{(2J^2 y - EJ + 2\pi\rho n_2 m)^2 + 4J^2(EJy - J^2 y^2 + 2\pi\rho n_2)}}{2J^2}$$

when $m = 0$ $\quad x = \dfrac{EJ - 2J^2 y \pm J\sqrt{E^2 + 8\pi\rho n_2}}{2J^2} = \dfrac{E - 2Jy \pm \sqrt{E^2 + 8\pi\rho n_2}}{2J}$

$= -y$ approximately.

when m becomes large $x = 1 - y$ " approximately

Problem.

A pulley 18" in diam. travels at a peripheral speed of 4000 feet per minute. It transmits at that speed a maximum activity of 12 horse-power. The belt encircles half its circumference. Find the least tension on the belt consistent with no slip at that delivery.

The pull on the belt, (difference of tension), will be

$$\frac{33,000 \times 12}{4000} = 99 \text{ lbs weight.}$$

The pull on the driving side will be $1.875 \times$ pull on following side.

$$99 + x = 1.875\,x$$

$$0.875\,x = 99$$

$$x = 113 \text{ lbs.}$$

For $\mu = 0.2$ The tension must be 212 lbs. on the driving side
113 " " " following side
and the mean tension at rest 163 lbs. weight.

Electrical Radiance experiments.

The receiver shown in diagramatic section facing p. 64 was exhausted by the Edelmann air-pump. In doing so the first time, an accident occurred which broke the top glass rod of the suspension. This was replaced with another very similar one, the constants of the apparatus therefore not altering greatly. The receiver was then exhausted till the pumpgauge showed no difference of level, probably representing about 0.4 mm of pressure. Inside the receiver, a similar gauge was placed to mark the maintenance of vacuum. The apparatus was then placed on one of the brick piers, and a beam from an arc light some 4 metres distant focussed upon it by a spherical mirror some 2 metres beyond. The heat of this beam was found to melt the shellac on the vanes and a screen had to be interposed, in the form of a water cell between glass sides. When the beam was thrown on the darkened vanes, the latter moved slowly towards the beam. Owing to the refraction of light passing through the wall of the glass receiver it was not possible to keep the plain vane in shadow. Finally with the beam directly on both vanes or in the centre between them the suspension slowly set parallel with the beam.

A weaker beam from a second more distant mirror was now thrown at right angles upon the apparatus, the first beam being suppressed. In about 20 minutes, the suspension was found to have turned to 45° or midway between the two directions.

The second beam was now suppressed and the original beam restored. In thirty minutes the suspension retreated 25° or so and was within some 20° of parallelism to the original beam.

It seems therefore that the suspension has a tendency to set itself along the beam, but whether from a true radiant pressure or from a convection effect in the rarefied air is not yet known. The plain mica seems to be most rapid. The deflections were slow but definite, and there was no wandering action.

Problem. A Crookes radiometer has an estimated mass of 0·5 grammes, and an estimated radius of gyration of 1 cm. A certain intensity of light produces in it a velocity of 70 revolutions per minute or an angular velocity $\frac{d\theta}{dt}$ of $2{\cdot}333\,\pi$. On intercepting the light the flywheel comes to rest in 15 seconds. Find the moment assumed uniform of friction round the axis.

The moment of inertia $= 0{\cdot}5 \times 1 \times 1 = 0{\cdot}5$ cm²gm.

" angular acceleration $\frac{d^2\theta}{dt^2} = \frac{2{\cdot}333\pi}{15} = 0{\cdot}4889$

" moment of friction $= 0{\cdot}244445$

The energy possessed by the flywheel at full speed $\frac{I}{2}\left(\frac{d\theta}{dt}\right)^2 = 13{\cdot}75$ ergs.

Standard Daniell cell for Bergmann & Co.

A c.p. zinc cylinder electroplated with zinc was opposed to a cp copper cylinder electroplated with copper. These were respectively immersed in a solution of $ZnSO_4$ 1·400 and $CuSO_4$ 1·100 @ 15°C respectively, these solutions being prepared with great care.

On first connecting up the cell a distinct e.m.f amounting to 0·86 volt was found in the reverse direction to that of the Daniell element. On examination this error was traced to the presence of an air bubble at the end of the capillary tube dipping in the $CuSO_4$. On expelling this bubble the E.M.F. immediately changed again to 1·090 volts. On closing the cells circuit through 1000 ω the p.d. fell to 0·01 volt showing the int. res. to be 12,000 ω. After cleaning the zinc plate with fresh glass-paper and replating the copper plate, the EMF returned to 1·078 volts.

Cautery Battery Test for The Edison Manufacturing Co. N. Y.

Eight elements of the double plate (3 zincs - 2 CuO frames) 300 amp. hr. type but in black g.p. cells of rectangular form, were enclosed in one box in two rows of four. The cells when charged held 1500 c.c. of solution sp.g. 1·26. A strip of german silver wound on a reel is included in the circuit.

The e.m.f. of the cells first made up was 7·3 volts = 0·91 p.c. The current started at 8·50 28th May. Two black ring, heavy leads, g.s. strip and knife cautery. The current was 18·8 amperes, the p.d. on the knife 0·667 volt (0·0355 ω)

The current was maintained until 15.50 making a total of 7.¾ hours or 131 ampere hours. The strength of the cells was at first a little in excess, but finally was just enough in ten or fifteen minutes after closing the circuit.

Continuation of Experiments on Telephone Battery (Edison-Lalande) from page 53.

The zinc in the cells were found to have lost so much since their last weighing, that some of them were replaced. They were then all arranged in numbers stamped upon them. It is supposed that the short circuiting which takes place in the cell is due to the bridging at the surface of the solution by a large number of small floating particles of metal. To prevent this from happening the plates are being now coated at the top with a varnish of gutta percha in $CHCl_3$ followed by a varnish of gum lolate in CS_2. This coat is carried down beneath the surface of the liquid. There are no couplings, the plates being separated by spreading them apart. New filtered solution was added to each cell.

No. of Cells	Weight of zinc gone 28.7.95									
1	30·305									
2	29·120									
3	33·945									
4	34·760									
5	32·000									
6	33·135									
7	41·600									
8	35·140									
9	31·290									
10	32·340									
11	33·965									
12	34·130									
13	33·458									

Alternating P.D.s for supplying lamps.

Mr R. Lozier found that at Station = Island the lamp circuit that had to be supplied gave 35°·30′ deflection on our Gardew Voltmeter. This was represented by 53 volts of continuous-current pressure here. The lamps should therefore be 53-volt lamps, and the mean alternating p.d. was 47·7 volts. If e be the instantaneous emf expressed by the relation

$$e = E \sin pt \qquad \text{where } n = \frac{2\pi}{p}$$

Then the energy delivered in one period thro a lamp of resistance r is

$$\frac{E^2}{r}\int_0^T \sin^2 pt\, dt. = \frac{E^2 T}{r\, 2}$$

so that a continuous current of $\frac{E}{\sqrt{2}}$ would produce the same heat

but $E = \frac{\pi}{2}\eta$ if η is the mean alternating emf.

$\therefore$ a continuous current of $\frac{\pi\eta}{2\sqrt{2}}$ or $1{\cdot}1\eta$ would produce the same effect

or $E = \frac{\pi\eta}{2\sqrt{2}}$

$\eta = 0{\cdot}9\,E$.

On the energy of luminiferous Ether.

Let the energy imparted to the surrounding ether by a ~~known~~ radiating point in space be η ergs per second, uniformly. Then in time t the energy delivered will be

$$E = \eta t$$

and the distance to which the disturbance will have travelled in every direction, is $r = vt$ where $v = 3 \times 10^{10}$ cms.

The volume V occupied by disturbance will be a sphere of

$$V = \frac{4\pi r^3}{3} = \frac{4\pi v^3 t^3}{3}$$

and the volume occupied per sec: or rate of expansion

$$\frac{dV}{dt} = 4\pi v^3 t^2$$

or $$dV = 4\pi v^3 t^2 dt$$

but this volume is filled by a quantity of energy delivered in time dt or $= \eta\, dt$

so that the energy per unit volume $\frac{dE}{dV}$ occupying this space

is $$\frac{dE}{dV} = \frac{\eta}{v} \times \frac{1}{4\pi r^2}$$

$$= \frac{\eta}{v} \times \frac{1}{S}$$

where S is the spherical surface considered.

The apparatus employed in the experiment on Electrical Radiation recorded in Book II p. 140 was again utilised. The lamp tube was sealed by seal into the main tube of the swinging vane, so that the latter should be directly under the influence of the rays of the 50 c.p. lamp. To ascertain the moment of torsion of the arrangement, a tin sphere 2·54 cms. in diam and weighing 62·23 gms was suspended by 1y. cms. of the same kind of platinum wire used in the suspension. The moment of inertia of the sphere would be

$$62 \cdot 23 \times 0 \cdot 4 \times 1 \cdot 613 = 40 \cdot 15 \text{ cm}^2\text{gms.}$$

This sphere executed 16 complete vibrations in 9 minute 0 sec. or find a period of approximately 33·75 secs.

The torsional rigidity of the wire is expressed by the equation

$$\tau = I\left(\frac{4\pi^2}{t^2}\right)$$

$$= \frac{40 \cdot 2 \times 19 \times 40}{33 \cdot 75^2 \times 33 \cdot 75} = \frac{40 \cdot 2 \times 760}{1139} = 26 \cdot 8 \text{ dyne cms.}$$

The length of the suspending wire in the radiance tube is about 10 cm so that the moment necessary to produce 1 deflection is 2·7 dyne cms

If the lamp absorb 150 Watts, 8% of that energy will be radiated as light. but $\frac{1 \cdot 5 \times 10^7}{3 \cdot 0 \times 10^{10}} \times \frac{1}{1200} = \frac{1}{20} \times \frac{1}{1200} = \frac{1}{24000} = \frac{1}{2 \cdot 4 \times 10^4} = 4 \times 10^{-5}$ erg

will be the energy at the disk per sec. But of this energy half should be numerically equal to the pressure say 20 microdynes. Now suppose that only 10% of all the energy in the carbon spiral due to the tube really enters it. Then the pressure will be 2 microdynes at a radius of 6 = 12 microdyne cms and the angle should be therefore

$$\frac{2 \cdot 9}{20 \times 10^6} = 10^{-5} = \frac{5 \cdot 7}{10^5} = 0 \cdot 00 \frac{3442}{10^5} = \frac{2011}{100} = 2'' \text{ of arc.}$$

On the Power required to operate a small Illuminating Plant for the Rick Telescope.

Six lamps of four candle power each are required three hours daily. A sample 16 c.p. lamp here takes 1.25 ampères at 9 volts p.d. Six of these = 7.5 ampères so that a battery of the double-plate Edison=Lalande type would easily operate it.

$$0.7x - 7.5 \times 0.03x = 9$$
$$0.475x = 9$$
$$x = 19$$

These would last certainly 250 amp: hr. = 33 hours.
= 11 days.

The energy absorbed would be $9 \times 7.5 = 67.5$ Watts $= \frac{1}{10}$ HP. say 10 cents per hour. or 30 cents daily. \$120 per annum.

Constants of the Smaller Cathetometer.

The screw has forty threads to the cm. Each revolution is divided into 100 parts and each hundredth can be read to 5 lb and estimated to 20 lb that is the instrument measures the $1/200000$ lb part and estimates the $\frac{1}{80,000}$ lb part of a cm. i.e. measures 5×10^{-5} and estimates 1.125×10^{-5}. One division of the vernier produces a motion movement of the optic axis (not exceeding) the wave length of sodium light. D. The instrument is in focus when the object is 6.0 cms from the object glass and the back lash is about 5 divs on the hand $\frac{1}{20}$ lb no or $\frac{5}{200}$ lb cm $= 1.125 \times 10^{-5}$

Constants of the Spherometer

The screw has forty threads to the cm, and its zero for a plane surface is 5.332. It measures the $\frac{1}{40000}$ lb of a cm. having 100 divs round the circle. $= 2.5 \times 10^{-6}$ cm.

By cathetometer the radius was too great to measure but by scale the distances

AB	5.64	OA	3.23	Mean 3.22 cm
BC	5.56	OB	3.205	
AC	5.62	OC	3.22.	

If x is the distance measured off in cms.

Rad: of curvature $R = \frac{5.184}{x} + \frac{x}{2}$

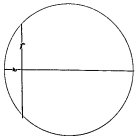
Curvature $\frac{1}{R} = \frac{2x}{5.184}$ or $0.192g\,x$ approximately.

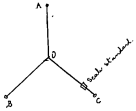
with the graduation of the instrument

$$R = \frac{207.36}{y} + 20y$$

$$\frac{1}{R} = \frac{y}{207.36} \text{ or } 0.00482 2y \text{ approximately. (c.o.s.)}$$

$0.4822\,y$ in dioptries (metre)





$x : r :: r + 2R - x :$

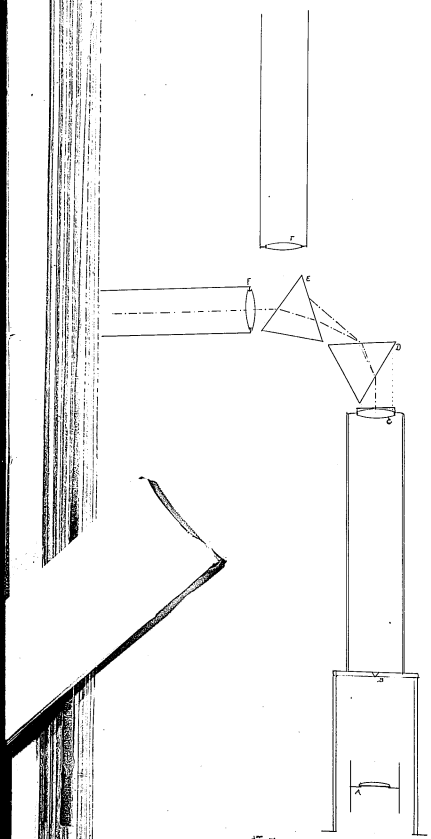
$2Rx = x^2 + r^2$

$R = \frac{x^2 + r^2}{2x} = \frac{r^2}{2x} + \frac{x}{2}$

$r^2 = (3.22)^2 = 10.368$

$\frac{r^2}{2} = 5.184$

$R = \frac{5.184}{x} + \frac{x}{2}$



Optical Measurements.

Glass lens No 1 Diam. 12·6 Plano convex $R = 42.5$ $C = 0.2615$
Large spherical Mirror no 1. $R = \cancel{\ldots}$ $C = 0.5885$ $F = \cancel{\ldots}$ cm
165·6 157·5

The radius of curvature of the glass by spherometer is 165·6
- " " " " " mercury - optical method - 157·5
- mean focal distance length 315.
- diameter of the aperture 33
- semi vertical angle taking $r = 160$ 5°55′
- solid angle subtended $\left(\frac{\text{area}}{r^2}\right)$ 0·03355
- area of reflecting surface 857. sq cm
- curvature 0·61 dioptrie or in C. G. S. U. 0·0061

Large spherical mirror no. 2

The radius of curvature of the glass by spherometer 161
- " " " " " mercury - optical method 150
- mean focal length 300
- diameter of the aperture 33
- semi vertical angle taking $r = 150$ 6°19′
- solid angle subtended 0·038815
- area of reflecting surface 858
- curvature 0·667 dioptrie or in C. G. S. U. 0·00667

On the Machines Required for the Lick Observatory Lights.

Contd from p. 70.

If the lamps are operated by a storage plant, then for 9 volts five would be required, and for a duplicate set 10. The capacity would be 22·5 amp hrs per diem say 25 with loss = 200 amp. hrs. for 8 days.

To charge these daily would be to supply 22·5 ampere for one hour.

The diagram on the opposite page represents the essential part of the stillson spectroscope in principal section ½ size. A is a cylindrical lens with plane face downwards and of 7 cm. focus. At or near its focus is the slit B, which is also in the principal focus of the ~~plano~~ convex lens (19 cm) C. D and E are equilateral prisms. F is a similar ~~plano~~ convex lens of 19 cm P.F. and the image it forms is examined by double eyepiece positive at the end of the drawtube.

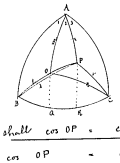
By spherometer the inner surface of the object glass in the Edison equatorial is plane, the reading of the outer surface being 3·39 thousd = $\frac{3.39}{240}$ cms, so that the radi of curvature is $\frac{5.1816}{3.39} \times 240 = 61.18$ cms, and the curvature $\frac{1}{R} = 0.01635$ c.g.s. or 1·6350 dioptrie.

By trial, the focal distance is about 163·5 cms.

Aperture 10·5 cms diam. (4·1/2″).

On another occasion an arc light distant 300 cms from the object glass was focussed 172 cms on the other side.

Proof of a continually recurring theorem in spherical trigonometry.



If ABC be a quadrantal spherical triangle formed by three equal rectangular coordinates, and OP be any arc, also if the direction angles are as shewn then.

shall $\cos OP = \cos l \cos\lambda + \cos m \cos\mu + \cos n \cos\nu$.

For $\cos OP = \cos m \cos\mu + \sin m \sin\mu \cos A_2$

$$\cos A_2 = \cos\left[\frac{\pi}{2} - (A_1 + A_3)\right]$$

$$= \cos\frac{\pi}{2}\cos(A_1 + A_3) + \sin\frac{\pi}{2}\sin(A_1 + A_3)$$

$$= \sin A_1 \cos A_3 + \cos A_1 \sin A_3$$

$$= \cos(A_1 + A_3)\cos A_3 + \cos A_1 \cos(A_1 + A_3)$$

$$= \frac{\cos n}{\sin m}\,\frac{\cos\nu}{\sin\mu} + \frac{\cos l}{\sin m}\,\frac{\cos\lambda}{\sin\mu}$$

$$\therefore \cos OP = \cos l \cos\lambda + \cos m \cos\mu + \cos n \cos\nu.$$

q.e.d.

On the Mean Amplitude of Sound Vibrations in air as deduced from the energy of vibration per unit volume.

(72)

Let the excursion of an air molecule from its position of rest at any moment, under vibration be x

- the period of vibration - T
- " frequency - - - $\nu = \frac{1}{T}$
- " amplitude - - - a having a maximum A
- " energy - the molecule be - e - - - E
- " mass - - - - m
- " n. of molecules per unit vol - n
- " mass of all the molecules - - - $M = mn$

Then we have if time be reckoned from the instant of excursion

$$x = A \sin\left(\frac{2\pi t}{T}\right)$$

$$\therefore \dot{x} = \frac{2\pi}{T} A \cos\left(\frac{2\pi t}{T}\right)$$

$$\therefore e = \frac{mn}{2}\frac{4\pi^2}{T^2}A^2 \cos^2\left(\frac{2\pi t}{T}\right)$$

$$\therefore e_{mean} = \frac{2\pi^2 mnA^2}{T^3}\int_0^T \cos^2\left(\frac{2\pi t}{T}\right)dt$$

$$= \frac{2\pi^2 mnA^2}{T^3}\left[\frac{2\pi t}{2T} + \frac{\sin\frac{4\pi t}{T}}{4}\right]_0^T$$

$$= \frac{2\pi^2 mnA^2}{T^2}(\pi)$$

$$= \frac{2\pi^3 mnA^2}{T^2}$$

$$\therefore A^2 = \frac{eT^3}{2\pi^3 mn}$$

$$A = \frac{\sqrt{e}}{\sqrt{(2T^3\pi^3 mn)}}$$

$$= \frac{\sqrt{e}}{\sqrt{2T^3\pi^3 M}}$$

For dry air at 0°C and pressure of 1 megadyne per sq cm,

$$M = 1.28 \times 10^{-3}$$

For the note do $\nu = 256 \times 10^2$ $\quad T^3 = 1.678 \times 10^7$

$\pi^3 = 3.14 \times 10^1$

denominator $= \sqrt{(1.28 \times 1.678 \times 3.14 \times 10^5)}$

$= \sqrt{6.7444 \times 10^5}$

$= \sqrt{67.444 \times 10^4} = 821$

$A = 0.00122\sqrt{e}$

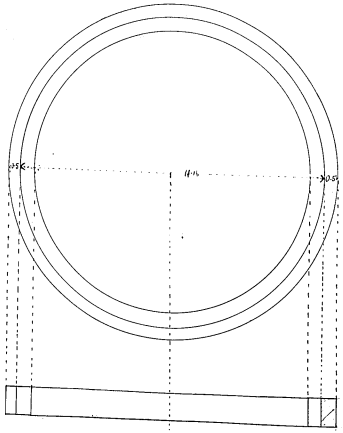
The maximum amplitude is therefore about one thousandth of the mean energy per c.c. stated in ergs.

Also $c = \dfrac{e - \varphi n w 10^{-8}}{r}$

$$= \frac{e}{r} - \frac{\varphi n w 10^{-8}}{r}\left(\frac{e}{\varphi n w 10^{-8}} - \frac{2\pi r M}{\varphi^2 n^2 w^2 10^{-16}}\right)$$

$$= \frac{2\pi M}{\varphi n w 10^{-8}}$$

Consequently. If the moment is constant the current will be constant at all speed.



Conditions for a motor to act as a Meter.

A motor whose field is supposed to be maintained uniform, drives under a varying e.m.f. e. find the conditions that the speed shall be proportional to e. (ills)

Let φ be the uniform flux c.G.S. U.

n - - no. of revs. per sec.

w - - - wires all round the armature.

γ - - counter e.m.f. (volts)

r - - - res: of the armature (ohms)

c - - current strength (amperes)

μ - - moment due to magnetic resistance

m - - - - - mechanical friction

ν - - - - - vane movement.

Then $e = c\mathcal{R} + \varphi n w \times 10^{8}$ equation of e.m.f.

$ec = c^2 r + 2\pi n(\mu + m + \nu)$ energy

From these c can be eliminated, and n expressed in terms of the remaining quantities.

$$e^2 - e\gamma = c^2 + \gamma^2 - 2e\gamma + 2\pi r n(\mu + m + \nu)$$

$$\therefore\ n = \frac{e\gamma - \gamma^2}{2\pi r(\mu + m + \nu)} = \frac{\varphi n w 10^{-8}(e - \varphi n w 10^{-8})}{2\pi r(\mu + m + \nu)}$$

$$2\pi r(\mu + m + \nu) = e\varphi w n^{-1} - \varphi^2 n^2 w^2 10^{-16}$$

$$n = \frac{-2\pi r(\mu + m + \nu) + e\varphi w 10^{8}}{\varphi^2 w^2 10^{16}}$$

$$= \alpha e + \beta$$

$$\frac{dn}{de} = a$$

The variations in speed will therefore be proportional to the variations of emf provided that the moments of friction and work at the axle are all independent of the speed, or that their sum is independent.

It is required to construct a motor which shall operate on 0.5 volt and make 500 revs. per min: on that amount. It must be as light as possible.

Suppose the int: diam: of the gramme ring to be 4.5 = 11.16 cms, and that the ring is of ~~triangular~~ section and 0.5 sq. cm.

If φ be 17000 $\varphi = 8{,}500$

for $n = \dfrac{500}{60} = 8.33$

$$0.5 = 8.5 \times 10^{3} \times w \times 8.33 \times 10^{-8}$$

$$\therefore\ w = \frac{0.5 \times 10^{5}}{70.81}$$

$$= 706$$

This is the number of wires which would drive 500 revs. per min when 0.5 volt is generated

It is desirable to have the starting moment as great as possible. Calling R the ext. radius this moment $\mathfrak{M}$ is

$$\mathfrak{M} = \frac{cw\varphi}{\pi R}$$

c being in abs measure
φ - - - -

The breadth of the armature being (on min) b and the depth a

- diameter - wire. (copper) - d
- thickness - insulation - t
- diameter covered - D
- number of layers - l

Then approximately

$$w = \frac{2\pi(R - \tfrac{1}{2}b)}{D} \times l$$

$$c = \frac{e}{\frac{2w(2a+2b)\rho}{\pi d^2}} = \frac{e\pi d^2}{2\rho w(a+b)}$$

$$w\varphi = \frac{e\pi d^2\varphi}{2\rho(a+b)}$$

and

$$\frac{w\varphi}{\pi R} = \frac{ed^2\varphi}{2R\rho(a+b)}$$

(all in abs. measure)

Consequently to a first approximation the starting moment with a given e.m.f. e is proportional to the square of the diameter of the wire, and inversely to the radius.

With 700 wires in two layers, there will be 350 on the first layer. The diam is 11·16 cm so that the allowance being made for insulation sections 360 wire must fit in 34 cm. = 0.0134 = 0.037". Allowing 0.005" for silk leaves 0.032" = #21 B.W.G.

The length of one turn will be $2(0.2 + 0.1) + 8 \times 0.03 = 1.5$". 700 turns = 1050" = 90 feet nearly. and the res: will be $\frac{90 \times 0.01}{4}$ = 0.225.

Supposing now that the full load is represented by 0·5 volt with 25 lamps, 1 lamp will give 0.02 volts. The current generated by this will be $\frac{0.02}{0.225}$ = 0.089 amperes. The starting moment will be

$$\frac{0.89 \times 10^{-1} \times 7.0 \times 10^2 \times 5.5 \times 10^3}{3.14 \times 5.5} = \frac{53.0 \times 10^4}{17.27} = 30{,}670$$

$$\frac{0.0220 \times 10^6 \times 0.81 \times 0.81 \times 8.5 \times 10^3}{2 \times 5.5 \times 1.7 \times 10^3 \times 1.5} = \frac{11.15 \times 10^7}{129.9 \times 10^3} = 3.73 \times 10^4$$

This moment of 30,670 dyne cms is equivalent to a couple of $\frac{30{,}670 \times 5.5}{981}$ at the circud. = 168 grammes = $\frac{1}{5}$ lb oz.

Solution for a speed of 150 revs per min and 1·0 volt at full load.

$$w = \frac{1.0 \times 10^8}{8.5 \times 10^3 \times 2.5} = \frac{100 \times 10^6}{21.25 \times 10^3} = 4.70 \times 10^3 = 4{,}700.$$

Since however there will be considerable fall of potential in an armature with so many turns, there will be a lower e.m.f generated, and we need only have 4,000 wire say.

These can be arranged in five layers of 800 or 4 of 1000.

in the first case, the diam will be $\frac{34}{800} = \frac{0.34}{8} = 0.043$ cm = 0.017" = 0.013"

- - second - - - - - $\frac{34}{1000} = 0.034$ cm = 0.0136 = 0.0096"

Assuming the first case 5 layers of 800 #29 B.W.G. 0.013"
The length of each turn will be 1.5" and 4000 turns = 6000"
= 500 feet ≈ 0.061 : 30.5 cm ÷ 1.4 = 7.6 cm and
The current that will at 100 volts through this will be for 25 amp
(full load) $\frac{1}{7.6}$ ampere, and for 1 amp $\frac{1}{7.6 \times 25} = \frac{1}{190} = 0.0053$ ampere.
The starting moment will be $\frac{1}{2} \times \frac{c u \omega}{\pi R} = \frac{1}{2} \frac{5.3 \times 10^{-1} \times 4.0 \times 10^{3} \times 8.5 \times 10^{3}}{3.142 \times 5.5}$

$$= \frac{1}{2} \frac{21.2 \times 10^{-1} \times 8.5 \times 10^{3}}{17.28} = \frac{1043}{2} \text{ dynes cm.}$$

$$= \frac{189.6}{2} \text{ dynes acting at inner periphery.}$$

$$= 0.193 \text{ grammes.}$$

$$= 0.097 \text{ "}$$

In as much as there will only be 1 sq. cm. of iron section through the armature (0.5 on each semi circumference), it will be unnecessary to have the iron in the core more than 5 sq. cm. for wrought iron or 10 sq. cm. for cast iron.

Allowing a clearance of 0.1 the maximum entrefer will be 0.4
The surface over which the flux enters is

$$3.14 \times 12.5 = 39.27 - 7.3 = \frac{32}{2} = 16 \text{ cms} \times 1 = 16 \text{ sq. cm}$$

The magnetic resistance is thus $0.4 \div 16 = 0.05$ units.
and the m.m.f. ~~exciting~~ power necessary for 17,000 lines is

$$17000 \times 0.05 = 850 \qquad \therefore 1.257\, AT = 850$$

$$\text{or amp} = 676$$

Suppose the magnets to be 6 cms long, and 4 cm in diam. The radiating surface will be 25 sq. cms. on each = 50 sq. cms. in all. Then allowing 20 sq. cms. per watt we have 2.5 Watts absorbed in the magnets. At 100 volts this will mean a current of $\frac{2.5}{110} = \frac{2.5}{1100} = 23$ milliamperes. The resistance of the magnets will therefore be $\frac{110}{23} = 0.023$ or $\frac{1}{\rho} = 47.80$ or = 24.00 in cal.

The diam. of the core will be 2.52 cm, the external diameter for trial 5 cm, and the length 6 cm. Then the coiling space = $6 \times 0.7854\,(25 - 6.35) = 87.9$ c.c.
and with silk covered wire $d = 0.005$

$$d = -0.005 \pm \sqrt{\left\{25 \times 10^{-5} + 0.000515 \sqrt{\frac{87.9}{2400}}\right\}}$$

$$\pm \sqrt{\left\{2.5 \times 10^{-5} + 0.000515 \times \sqrt{3.662}\right\}}$$

$$\left\{2.5 \times 10^{-6} + 0.000515 \times 1.914\right\}$$

$$0.000025 + 0.000986$$

$$\pm \sqrt{0.00019} = \sqrt{19.19} \times 10^{-4} = 3.14 \times 10^{-2}$$

$$\pm 0.0314$$

$$= \pm 0.0264 \text{ cm}$$

$$= 0.0105 = \#31 \text{ B.W.G.}$$

1.2 ω per foot = 2000 feet = 0.6 lbs on each

Specific Gravity of 3 samples of Samarskite

Catalogue $\frac{478}{2000}$ Edison Collection.

6th June 90.

Weight of $\frac{478}{2000}$ in air		6·8655		
	- equivalent	5·5200		
		1·3455	= 5·103	
" small smaller piece	in air	1·1795		
	" H_2O	0·9485		
		0·2310	= 5·105	Mean 5·105 ± 0·0008 × sp. gr. of H_2O @ 25° C = 0·9970 = 5·090 × max. density of H_2O.
" " "	" air	1·3890		
		1·1170		
		·2720	= 5·106	

On the winding of a Phonoplex coil which shall take only half the present current while retaining the same inductance.

The dimensions of a #2 standard coil see book II p 101

$l = 9.9 \quad x = 6.15 \quad y = 2.15$

Area $29.7057 - 3.6305 = \text{Diff } 26.0752$.

Vol $= 26.075 \times 9.9 = 258$.

The thickness of silk is 0.003" , 0.0075 cm. $= 7.5 \times 10^{-3}$

$\frac{l}{2} = 3.75 \times 10^{-3}$

$(\frac{l}{2})^2 = 14.06 \times 10^{-6} = 1.4 \times 10^{-5}$

0.000015

$$d = -0.0074 \pm \sqrt{\{0.000.02 \pm 15\sqrt{\frac{360}{13.7}}\}}$$

$\pm 15\sqrt{25.50}$

$\pm 15 \times 5.05 \times 10^{-3}$

$\sqrt{\quad + 7.724 \times 10^{-3}}$

$\sqrt{(7.724 \times 10^{-3})}$

$\sqrt{(77.24 \times 10^{-4})}$

8.8×10^{-2}

$+ 0.088$

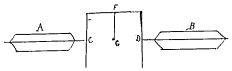
$= 0.0814$ cm.

$= 0.033''$

The nearest wire to this is #21 B.W.G. 0.032".

10.2 w of this @ 0.3074 lbs. per w = 3.135 lbs.

The wire used by Bergmann to fill the present coil #2 is #20 B.W.G. 0.035 and the resistance of this has to be doubled. the diam should be diminished to $\sqrt{\frac{1}{2}} \times 0.035 = 0.814 \times 0.035$ $= 0.029''$ Nearest number #21 B.+S.



The general equation of energy is as follows:—
Let $\mathcal{E}$ be the energy delivered from the supply line.

e_1 . . . . . to A (for friction)
e_2 . . . . . B (- - -)
η . . . . . B & A
ε . . . . . to the car

Then there are two cases
1st When the energy ε is less than e_1 the frictional losses magnetic, mechanical, and electrical in the motor and motor wheel.
2nd When ε is on the contrary greater than ε.

For the first case
$$\mathcal{E} = 2f + \varepsilon$$
$$e_1 = f + 2\varepsilon$$
$$e_2 = f - \varepsilon$$
$$\eta = 0$$

. . second case
$$\mathcal{E} = 2f + \varepsilon$$
$$e_1 = 2f + \varepsilon$$
$$e_2 = 0$$
$$\eta = \varepsilon - f$$

On the equations of motion for the new mitre gear system of car driving with two motors. (7)

The notation is the same as that on p 65.
In the two motors A and B.
Let w be the number of wires counted all round the armature
n_1, n_2 " - - - - revs. per sec: made by each
$\varphi_1 \varphi_2$ - - 8th phases through each.
ρ - - revs. of each armature (assumed equal)
E - - E.M.F. of supply (assumed fixed)
m - - tractive moment of the car round C.
μ - - moment of magnetic + mechanical friction
M, M_2 - - - of work on motor shafts
$\eta_1 \eta_2$ - - e.m.f. generated by each armature.

The two armatures are in parallel. The fields are excited separately.
Then 1st to reach the simplest case, assume $\rho = 0$ $\mu = 0$.

Then
$$2\pi n_1 M_1 = 2\pi n_2 M_2 + 2\pi \frac{(n_1 - n_2)}{2} m.$$
$$\text{but } M_1 = M_2 = M$$
$$2\pi n_1 M = 2\pi n_2 M + 2\pi \frac{(n_1 - n_2)}{2} m$$
$$\therefore m = 2M$$
$$2\pi n_1 M = E c_1$$
$$2\pi n_2 M = E c_2$$
$$\therefore E c_1 = E c_2 + 2\pi \frac{(n_1 - n_2)}{2} m$$

but these two terms on the right hand side must be equal

$$\therefore \frac{2\pi (n_1 - n_2) m}{2} = \frac{E c_2}{2}$$

Or the work done on the car will be half the energy absorbed by the motor, and the current in the dynamo will be half the current in the motor. If the car takes 5 HP. to run it then the motor will be absorbing 10 HP the dynamo will be generating 5 HP, and the system will be absorbing 5 HP.

3rd case. Friction considered but no revs: in armatures $\rho = 0$ $\mu > 0$

$$2\pi n_1 (M_1 - \mu) = 2\pi n_2 (M_2 + \mu) + 2\pi \frac{(n_1 - n_2)}{2} m$$

(but $M_2 + \mu = M_1$) $\quad E c_1 = \left\{ E c_2 + 2\pi n_2 \mu \right\} + \left\{ 2\pi \frac{(n_1 - n_2)}{2} m \right\}$

the two at back terms are equal

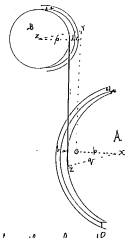
$$\therefore \text{in all cases } 2\pi \frac{(n_1 - n_2)}{2} m = E c_2 + 2\pi n_2 \mu$$

$$\therefore c_1 = c_2 + \frac{2\pi n_2 \mu}{E} + \frac{2\pi (n_1 - n_2) m}{2E}$$

Or the following motor will cease to absorb energy when the work done on the car is equal to its friction. It then becomes a friction clutch, + no current flows in its circuit but the energy supplied to the leading motor is still twice the energy required to drive the car. As the load on the car increases the following motor becomes a dynamo, and the above equation is still true.

Problem. Two pulleys run on axes fixed at right angles and a rope passes at right angles to each axis tangentially from the center of the face of one to the center of the face of the other. Determine the least free length of rope when the dimensions of the rims are given.

With the dimensions represented in the diagram, the rectangular coordinates of the opposed clips in the plane xz are



	X	Y	Z
For the wheel A	$(p-a)$	0	$(q+b)$
" " idler B	$(p+c)$	y	$(q-d)$

Then the coordinates of a point on the rim of the wheels at an elevation $Y = \bar{y}$ above the plane of xz are

For A	$(p-a)$	$\bar{y}$	$\sqrt{(q+b)^2-\bar{y}^2}$
" Idler B	$\sqrt{(p+c)^2-(y-\bar{y})^2}$	$\bar{y}$	$(q-d)$

Let the distance y be such that the rims then just touch. If the separation y or free length of the rope be made equal to this distance, we have the condition

$$\sqrt{\left\{(p-a)-\sqrt{(p+c)^2}\right\}^2+\left[\left\{\sqrt{(q+b)^2-\bar{y}^2}\right\}-(q-d)\right]^2} = 0$$

$$\text{or} \quad -(a+c)^2+\left\{\sqrt{(q+b)^2-\bar{y}^2}-(q-d)\right\}^2 = 0$$

$$\text{or} \quad \sqrt{(q+b)^2-y^2} = q-d \pm (a+c)$$

$$\therefore \quad (q+b)^2-y^2 = (q-f)^2 \quad \text{where } f = a+c+d$$

$$y^2 = (q+b)^2-(q-f)^2$$

$$y = \sqrt{(q+b)^2-(q-f)^2}$$

In a practical instance

$$a = 1$$
$$b = 0.6$$
$$c = 0.6$$
$$d = 1$$
$$q = 7.8$$
$$\therefore f = 2.6$$

$$y = \sqrt{(7.8+0.6)^2-(7.8-2.6)^2}$$
$$= \sqrt{8.4^2-5.2^2}$$
$$= \sqrt{70.56-27.04}$$
$$= \sqrt{43.52}$$
$$= 6.6$$

To determine the winding and dimensions of a quadripolar 18 kwt motor whose armature is to be 20" in diam, and whose peripheral speed is to be 4000 feet per min: the normal emf to be 15 volts generated.

The peripheral speed is 2000 cms per sec: and the diam. = 50.8 cms., so that the number of revs: per sec. = 12.53 or 750 per min.

Consequently $\Phi w = \frac{15}{12.5} \times 10^8 = 1.2 \times 10^8$

18 kilowatts @ 15 volts = 1200 amperes. The fall of potential in the armature must not exceed one volt, or the total res: must not exceed the $\frac{1}{1200}$th of one ohm.

Assume as a trial value 4" square to be the section of armature compressed copper wire. The iron will occupy 70 % of this space or 11.2 sq in = 72.24 sq. cms. If the normal induction be 13,000 this represents a value of Φ = 939,000 But making Φ = 1,000,000 normally, we can employ 120 compound bars round the armature.

If the radial depth of iron be 4.25" = 10.8 the % space 60 and induction 13,000 then $b = \frac{1,000,000}{\frac{10.8}{2.46} \times 13,000 \times 0.6} = 11.86$ cms = 4.68"

This breadth being too great, we may try 160 bars in which case $\Phi = \frac{1.2 \times 10^8}{1.5 \times 10^4} = 800,000$, and $b = 3.73" = 9.52$ cms.

If the thickness of the bars on top be 0.275" = 0.7 cm. below to 0.4" or 1 cm and on the sides be also 0.7 cm. then the resistance of the closed copper shell over round the wire would be

Upper and outer edge	9.5 cms long	$\pi \times 50$ broad	and 0.7 thick	$= \frac{9.5}{157.07}$	= 0.0836
Under - iron	19.0 -	$\pi \times 25$	-	- 1.0	$= \frac{19}{79 \times}$ = 0.1266
Two sides	12 -	35%	-	- 0.7	$= \frac{24}{77}$ = 0.3117
					0.5219

Total $0.5222 \times 18.00 = 9.40 \times 10^{-3}$ ω.

For 150 turns = $9.40 \times 10^{-3} \times 2.25 \times 10^{-4} = 21.15 \times 10^{-3}$

This ÷ 16 for a quadripolar machine = 1.32×10^{-3} = 0.0013 ω.

If the peripheral speed be increased to 5000 ft per min (2500 cms per sec) the revs: will be 15.67 per sec, or 940 per min.

Then $\Phi = \frac{1.5 \times 10^8}{1.567 \times 1.60 \times 10^3} = \frac{1.5}{2.508} \times 10^4 = 600,000$

For an induction density of 13,000.

$$\frac{13000 \times 9.5 \times \pi \times 0.60}{2} = 600,000$$

$$= \frac{6.0 \times 10^5}{6.0 \times 10^{-1} \times 1.3 \times 10^4 \times 9.5 \pi} = \frac{10^5}{1235 \times 10^3} = 81 \text{ AT}$$

$$= 3.19"$$

Each magnet will contribute 300,000 lines say with leakage 1,500,000 lines at a density (cast iron) of 7000 = 65 sq. cms = 9.1 cms = 3.6" diam.

Motor Calculations continued.

The reluctance of the air spaces will be as follows—
Each magnet cap will cover 67° of outer periphery = 1 radian circumference = $2\pi \times 25.4$ ∴ cap covers 25.4 cms. The breadth of iron will be 7.6 cms so that the area = 193 sq. cms. The entrefer here is 1 cm.

The area covered by the sides of the cap will be
$\pi(24.7^2 - 15.1^2) = 1901 - 179 = 1722$ sq. cms $- 40 \times 12.5$ (500)
$= 1222 \div 4 = 305$ sq. cms. The entrefer is here 1.0 cm.
The reluctance for air spaces is therefore

$$2\left(\frac{1.0}{6.0047}\right) + \frac{.2}{800} = 0.0025 \text{ limit.}$$

To force 1500,000 lines through this will require a M.M.F of
$2000 = 1.257 \times 1590$ or 800 A.T. on each limit, assuming negligible reluctance in the remainder of the circuit.

The external diameter of the magnets will be 11.7 cms the circumference 36.75. Their length is 12.5 = 25 for a pair the total surface on a pair is thus 920 sq. cms., and allowing 20 sq. cms per watt = 46 Watts, @ 15 volts = 3.0 amperes, or 6 amperes if all four are one side be in series.

The coiling space is on each core 12.5 x 4 cm.

~~Requirements for a Wire Armature of equal power.~~

The coiling space on each magnet core is $14\pi(7.25^2 - 2.75^2)$
$= 14 \times (53.9 - 7.9) = 14 \times 83 = 1162$ c.c.
The resistance is to be 1.25 ω each

$$d = 0.02 + \sqrt{0.00004 + 0.00153 \times \sqrt{\frac{1162}{1.25}} \times \sqrt{929.6} \times 30.5} + 0.004666$$

$$+ \sqrt{0.0471} = \sqrt{4.71 \times 10^{-2}}$$

$$+ 0.217$$

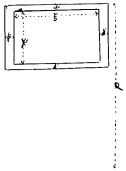
$$= 0.237 \text{ cm}$$

$$= 0.093'' \quad \text{#13 B.W.G. } 0.095''$$
$$\text{#11 B.S. } 0.091''$$

Taking 0.091. this has 20 lbs per ω, so that 1.25 ω = 25 lbs. and 8 spools will require 200 lbs. weight. This wire has 800 feet per ohm = 20000 feet in all. The mean diameter will be 0.4 feet, the mean circumference 1.25 feet, and the number of turns $\frac{20000}{1.25} = 16,000$. $= \frac{48000}{8}$ A.T. = 6000 A.T.

This exciting power will really be increased by if the diameter of external winding be reduced to 1.5 above iron and the weight on all the fields be reduced 120 lbs. = 15 lbs on each. All in series this will represent for $\frac{5\omega}{8} = 0.625\omega$ each = 0.042 ω per lb. = #13 B.W.G. 0.095". This wire has 874 feet per ω so that it has 546 feet on each spool. = 410 turns. = 12 ohms
= 2500.

With 160 lbs. weight on all in series for 5 ω = 32 lbs. per ohm = #10 B.S. wire. 0.102". = 20 lbs on each core @ 31.8 feet = 636 feet = 470 turns = 1410 A.T. = 2820 exciting power 3530 m.m.F.
60 turns per layer x 8 layers.



To commence with an approximation to the best value for w

let $\xi = \nu\psi$ and $a = \lambda\beta$

Then (10) becomes $$\frac{\nu\psi}{\lambda\beta} + \frac{\psi}{\beta} = \frac{\pi p^2 K r \rho_m}{\sigma w^2} \qquad (12)$$

and (11) $$\nu\psi w = \frac{\varepsilon\, 10^8}{2 n w u b} \qquad (13)$$

$$\frac{\nu\psi\beta}{\left(1+\frac{\nu}{\lambda}\right)} = \frac{\varepsilon\, 10^8}{2 n w u b} \times \frac{\sigma w^2}{\pi p^2 K r \rho_m} \qquad (14)$$

$$w = \frac{\nu\psi\beta\lambda}{\lambda+\nu} \times \frac{2\pi p^2 K r \rho_m\, n w u b}{\sigma\, \varepsilon\, 10^8} \qquad (15)$$

Formulae useful in the design of Motors.

Let e be the e.m.f. required from the motor at no load.
" r " " res. (ω) of the armature between brushes.
" q " " coefficient of e forming the maximum permissible drop at full load.
" p " " number of poles in the machine
" ρ_m " " res. (ω) of the ending space of armature considered as one turn.
" n " " number of wires or bars counted all round.
" n " " number of revs. per second.
" K " " coeff. of useful space occupied in the winding, after insulation &c.
" u " " coeff. of useful work in the armature space.
" Φ " " total flux through each pole head into the machine $\times 10^8$
" a " " breadth above of the conductor
" β " " " on one side ..
" γ " " " below ..
" δ " " " on the other side ..
" ξ " " " breadth of iron space
" ψ " " " depth " " " radially.
" ρ " " " ext. rad. of the armature
" J " " ~~strength~~ typ of the machine in watts at full load
" c " " current in " " (amperes) " " "

The first consideration is the power. This is generally determined by the drop, for if the drop at full load be not great the heating will not be excessive. Hence

$$c = \frac{J}{\varepsilon - qe} \qquad (1)$$

$$\cancel{\frac{\sigma J}{\varepsilon - qe} = q(\varepsilon)} \quad \therefore \frac{Jr}{\varepsilon(1-q)} = qe \qquad (2)$$

$$r = \frac{qe^2(1-q)}{J} \qquad (3)$$

To close approximation $$t_0 = \frac{\sigma}{2\pi}\left[\left\{\frac{\xi + \frac{(\beta+\gamma)}{2}}{a\rho}\right\} + \left\{\frac{\xi + \frac{(\delta+\delta)}{2}}{\gamma(\rho-\psi)}\right\} + \left\{\frac{\psi + \frac{(a+\frac{\gamma}{2})}{\delta(\rho-\frac{\xi}{2})}\right\} + \left\{\frac{\psi + \frac{(a+\frac{\gamma}{2})}{\beta(\rho-\frac{\xi}{2})}\right\}\right] \qquad (4)$$

σ = resistivity of copper (ω)

$$\therefore r = \frac{\sigma w^2}{2\pi K p^2 (X)} \qquad r = \frac{r_0 w^2}{p K} \qquad r_0 = \frac{\sigma p^2 K}{w^2} \qquad (5)$$

Also $$\varepsilon = \Phi n w \qquad (6)$$

and if Φ is the normal working induction, $$\Phi \times 10^8 = a\xi\psi b \qquad (7)$$

Less accurately (4) may be written $$r_0 = \frac{\sigma}{2\pi\rho_m}\left\{\xi\left(\frac{1}{a} + \frac{1}{\gamma}\right) + \psi\left(\frac{1}{\delta} + \frac{1}{\beta}\right)\right\} \qquad (8)$$

where $\rho_m = \left(\rho - \frac{\psi}{2}\right)$ and if $\left\{\begin{matrix}\alpha = \gamma \\ \beta = \delta\end{matrix}\right\}$ $$r_0 = \frac{\sigma}{2\pi\rho_m}\left\{\frac{\xi}{a} + \frac{\psi}{\beta}\right\} \qquad (9)$$

roughly $$\therefore \frac{\xi}{a} + \frac{\psi}{\beta} = \frac{\pi p^2 K r \rho_m}{\sigma w^2} \qquad (10)$$

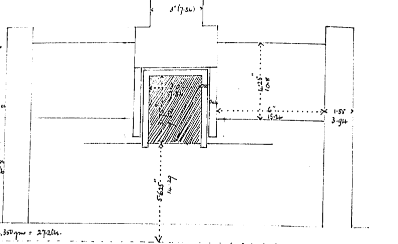
and $$\xi\psi = \frac{\varepsilon \times 10^8}{2 n w u b} \qquad (11)$$

Generally a motor is designed with given or assumed values of ρ, n, ε and J. From these we can select a trial value of w. This gives by equation 11 the cross section of armature body $\xi\psi$. The ratio of ξ to ψ will generally be suggested by mechanical considerations and by the position of the magnets. Thus ξ and ψ are found. Suitable trial values of a and β must now be determined which will satisfy the approximate relation (10) the entafer being kept in view. The more accurate equations (4) + (5) must then be satisfied. If these will not enable convenient values to be obtained another value of w must be tried in (11). Equation (15) gives a preliminary value of w in terms of ψ and β.

Section through magnet poles of quadripolar motor

1/4

Volume of iron core space 8756 c.c.
@ sp. g. 4.9 = 42,900 gms
= 94.6 lbs.
160 bars each 6.5 oz
Total 65 lbs.
Vol: of copper in conts 4680 cc
= 91.8 lbs.
Total copper in arm. 156.8 lbs.
Magnet wire 8 × 20 = 160 lbs.
Diam. of cores 10.7 area 89.9
Length - - 15.25 vol. 1371 cc
Mass - - 10,700 gms = 23.6 lbs
8 cores = 188.8 lbs.
Frame approximate dimensions
3.94 × 2922 × 7.8 = 89,822 gms
= 198 lbs. 2 = 396 lbs.
Shaft 30 × 2.54 × 20.26 × 8 = 12,350 gms = 27.2 lbs.



Total estimated weight of armature 375 lbs. } 1425 lbs.
- - - field frame 1050 - }

Armature iron wire 0.032" before oxydising

Magnetic Data.

Useful flux through each pole 1,000,000 each core 500,000, each yoke 250,000, each segment of armature 500,000

Total - - - - 1,500,000 - - 750,000 - - 375,000 - - - - 500,000

$\mathcal{B}$ mean - - - - - - 8,330 - - 7000 approx. - - - - 6930

Length of circuit in iron by any one path 70 cms. in armature 15 cms.

Reluctance - - - - - - - - $\frac{70 \times 0.010}{70}$ = 0.010 l = 0.01 ÷ 20.005 - armature negligible.

Area of polar face about 800 sq. cms.

Length - interfer - 1

Reluctance of air space about 0.0025 Total reluctance about 0.008 l.

The m.m.f. for 1,500,000 lines thro' 0.008 = 12,000 = 1000 A.T.

Each core has 20 lbs = 471 turns (in 8 layers) of # 10 B & S. carrying 3 amps.

= 1410 A turns = 2820 A.T. in both. All 8 cores in series = 5 ω

160 bars in armature 1 commutator. 4 brushes. or 4 pairs of brushes.

equivalent res: of armature = 10 bars.

Test of Lightning Protectors for the Edison Lamp. Co. and for the United Edison Mfg. Co.

Two Wirt lightning arresters with 20 brass washers were tested for the Lamp Co., and two with 26 iron washers for the Manufacturing Co. of 65 5th Ave.

The Municipal dynamo was connected directly to the arrester and operated at about 1000 volts p.d. The Holz machine was used to charge 6 Leyden jars, and the discharge spark was caused to pass over the washers and disks of mica. The washers were cut out in turn by a short circuiting wire, until the arc followed from the dynamo. This occurred at two disks in one case (iron) and three for all the others.

Revision of Calculation for the Bar armature.

$J = 18{,}000 \quad \varepsilon = 20 \quad \varphi = 0.1$

$\therefore r = \frac{0.1 \times 400 \times 0.9}{18{,}000} = \frac{0.9 \times 40}{18{,}000} = \frac{36}{18} \times 10^{-3} = 0.002\ \omega$

$w = 160 \quad u = 0.6 \quad n = 13 \quad \mathcal{B} = 12{,}000 \quad \varepsilon = 20$

$\therefore \xi\psi = \frac{20 \times 10^{9}}{2 \times 1.3 \times 1.6 \times 0.6 \times 1.2 \times 10^{7}} = \frac{10^2}{1.5} = 66.7$ sq. cms.

$\xi = 7.6 \quad \psi = 9.5 \quad \therefore \xi\psi = 72.2$ sq. cms.

$K = 0.8 \quad p = 4 \quad r = 0.002 \quad w = 160.$

$\therefore r_0 = \frac{0.002 \times 16 \times 0.8}{160 \times 160} = \frac{2.0 \times 1.6 \times 0.8 \times 10^{-2}}{2.56 \times 10^{4}} = 1 \times 10^{-6}\ \omega.$

$\therefore 1 \times 10^{-6} = \frac{1.75 \times 10^{-6}}{2 \times 3.14} \left\{ \frac{7.6 + \beta}{\beta \times 24} + \frac{7.6 + \frac{\beta}{2} + 1.3}{2.5 \times 13} + 2\left(\frac{9.5 + \frac{\beta}{2} + 1.3}{\beta \times 19}\right) \right\}$ grouping

$= \frac{1.75 \times 10^{-6}}{6.28} \left\{ \frac{7.6 + \beta}{24\beta} + \frac{17.8 + \beta}{65} + \frac{21.6 + \beta}{19\beta} \right\}$

$\left\{ \frac{0.3167}{\beta} + 0.0417 + 0.274 + 0.0154\beta + \frac{1.137}{\beta} + 0.0526 \right\}$

$1 = 0.2787 \left(0.0154\beta + \frac{1.454}{\beta} + 0.369 \right)$

$1 = 0.004291\beta + \frac{0.4052}{\beta} + 0.1028$ if β is about 1

$1 = \frac{0.4052}{\beta} + 0.1071$ → recorrecting $1 = \frac{0.4052}{\beta} + 0.1045$

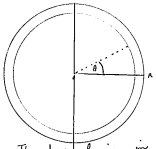
$0.893\beta = 0.4052$ $\quad$ $0.8955\beta = 0.4052$

$\beta = 0.4$ $\quad$ $\beta = 0.45 = 0.178"$

By doubling this, we shall have only one volt drop in armature.

The thickness selected will be 0.325"

On the number of turns of binding wire needed on the periphery of an armature to overcome the centrifugal force of the bars, assuming these to be held in contact entirely by the tension of the wire binding.



Let the figure represent a section of the armature by a plane at right angles to the axis. Let n be the number of bars

m . . mass of each bar

M = mn . total mass.

v = velocity of the c.i. of bar.

ω = ang. vel. . . . . .

Then consider the forces resolved parallel to OA

The bar lying in plane OA exerts a pull $\frac{mv^2}{r}$

. . making an angle $+\frac{2\pi}{n}$ . . . $\frac{mv^2}{r}\cos\left(\frac{2\pi}{n}\right)$

. . . . . $+\frac{4\pi}{n}$ (2) . . . $\frac{mv^2}{r}\cos\left(\frac{4\pi}{n}\right)$

. . . . . $\frac{2\pi}{n}\times\frac{n}{2}$ . . . $\frac{mv^2}{r}\cos\left(\frac{\pi}{2}\right)$

and the bars making similar negative angles give an equal pull each to each, in the same direction.

$$\text{Total pull} = 2\frac{mv^2}{r}\left(\cos\frac{2\pi}{n} + \cos\frac{4\pi}{n} + \cos\frac{6\pi}{n} + \quad + \cos\frac{n}{2}\frac{2\pi}{n}\right)$$

This is a well known trigonometrical series, always capable of definite arithmetical solution. For most purposes however it will be sufficient to consider $n = \infty$

Then the force exerted by an element of the ring $+d\theta$ will be

$$df = \frac{M d\theta}{2\pi}\frac{r^2\omega^2}{r}\cos\theta = \frac{M d\theta}{2\pi}r\omega^2\cos\theta$$

The total force acting normal to the plane BOC will be

$$F = \frac{Mr\omega^2}{2\pi}\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}}\cos\theta\, d\theta = \frac{Mr\omega^2}{\pi} = \frac{1}{\pi}\frac{Mv^2}{r}$$

Consequently the tension on the binding wire due to centrifugal force will be $\frac{1}{\pi}$ the centrifugal force due to the whole weight of the bars collected at one point. It will therefore be sufficient to make the power of the binding wire $\frac{Mv^2}{r}$ or $\left(\frac{Mv^2}{g\,r}\right)$ lbs. tension, v being expressed in ft per sec. r in feet $g = 32$ and M in lbs. mass

On the Mathematical laws of the Impact of moving bodies, compatible with Newton's coefficient of restitution.

Let M and $M_1 = \alpha M$ be the masses of impinger(I) and impinge(J) respectively
V - $V_1 = \beta V$ - - initl velocities " " " "
v - - common - - - - - -
U - U_1 - - final - - - - - -
ε - - coefficient of restitution.

Then the following conditions will hold,

Body	Velocity	Mass	Momentum	Change of Momentum	Kinetic Energy	Change of energy	Total energy	Change of totl
I	V	M	MV	-	$\frac{MV^2}{2}$		$\frac{MV^2+M_1V_1^2}{2}$	-
J	V'	M'	$M'V'$	-	$\frac{M'V'^2}{2}$	-	$\frac{MV^2}{2}(1+\alpha\beta^2)$	.
	βV	αM	$MV\alpha\beta$	-	$\frac{MV^2}{2}(\alpha\beta^2)$	-		
I	v	M	Mv	$-M(V-v)$	$\frac{Mv^2}{2}$	$-\frac{M}{2}(V^2-v^2)$		
	$V\left(\frac{1+\alpha\beta}{1+\alpha}\right)$		$MV\left(\frac{1+\alpha\beta}{1+\alpha}\right)$	$-M\left\{V\left(1-\frac{1+\alpha\beta}{1+\alpha}\right)\right\}$	$\frac{MV^2}{2}\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{MV^2}{2}\left\{1-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$	$\frac{MV^2}{2}\frac{(1+\alpha\beta)^2}{1+\alpha}$	$\frac{MV^2}{2}\frac{\alpha(1-\beta)}{1+\alpha}$
				$-MV\left(\frac{\alpha(1-\beta)}{1+\alpha}\right)$	$\frac{MV^2}{2}\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{MV^2}{2}\left\{1-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$		
J	v	M'	$M'v$	$-M_1(V_1-v)$	$\frac{M_1v^2}{2}$	$-\frac{M_1}{2}(V_1^2-v^2)$		
	$V\left(\frac{1+\alpha\beta}{1+\alpha}\right)$		$MV\alpha\left(\frac{1+\alpha\beta}{1+\alpha}\right)$	$-\alpha MV\left(\frac{1-\beta}{1+\alpha}\right)$	$\frac{MV^2}{2}\alpha\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2$	$-\frac{\alpha MV^2}{2}\left\{\beta^2-\left(\frac{1+\alpha\beta}{1+\alpha}\right)^2\right\}$		
I	U	M	$MV\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$-M(v-U)$	$\frac{MU^2}{2}$	$-\frac{M}{2}(V^2-U^2)$		
	$V\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$			$MV\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\frac{MV^2}{2}\left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$	$-\frac{MV^2}{2}\left[1-\frac{\{1+\alpha\beta-\varepsilon\alpha(1-\beta)\}^2}{1+\alpha}\right]$		
J	U'	M'	$M'U'$	$-M(v-U')$	$\frac{M'U'^2}{2}$	$-\frac{M'}{2}(V_1^2-U_1^2)$	$\frac{MV^2}{2}\left(\phi^2+\alpha\psi^2\right)$ where $\phi = \left\{\frac{1+\alpha\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$ and $\psi = \left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\frac{MV^2}{2}\left(\phi^2+\alpha\psi^2-\beta^2\right)$
	$\left\{\frac{\alpha+\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$		$MV\left\{\frac{\alpha+\beta-\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}$	$\varepsilon MV\left\{\frac{\alpha-(1-\beta)}{1+\alpha}\right\}$	$\frac{\alpha MV^2}{2}\left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$	$-\frac{M'}{2}(\alpha\beta)\left\{\beta^2-\psi^2\right\}$ $\therefore \phi^2 = \left\{\frac{\alpha+\beta+\varepsilon\alpha(1-\beta)}{1+\alpha}\right\}^2$		

These expressions are capable of great simplification under special conditions. For example as the simplest case let $M = M'$ and $\varepsilon = 1$ $\therefore \alpha = 1$
The change in kinetic energy then becomes 0.
In the next simplest case let $\varepsilon = 1$ but $M \geqq M'$.
Then the change in kinetic energy of the system becomes $2MV^2\frac{\alpha}{(1+\alpha)^2}(1-\beta)(\alpha^2-1)$
If $\beta = \infty$ $\varepsilon \frac{MV^2}{2}\frac{4\alpha(\alpha^2-1)}{(1+\alpha)^2}$

Angle of solar dispersion 21. VI. 90 $\tan^{-1}\frac{1}{30'} = \frac{1}{360} = 0.00277 = 0°\,9'.20''$

Dimensions and Data of Copper wire Helix after rewinding
May 1890.

1st layer	103 turns		9th layer	103 turns.		Length overall	16.25"
2nd	103	"	10th	103	"	Outer flange	15.25
3rd	103	"	11th	102	"	Int. diam.	4.58
4th	104	"	12th	102		Out. "	5.25
5th	102	"	13th	102		Flange "	10.4
6th	102	"	14th	102		Layers	17
7th	103	"	15th	102		Turns	1742
8th	103	"	16th	101		Turns per cm =	114.2
			17th	102.			

Test of the magnetic susceptibility of different specimens of ore.
June 22nd 1890.

Five parallelopipeds were ground and faced very fairly true from different samples of ore. The above coil was situated at right angles to the magnetic axis of the Gauss magnetometer and distant 121 cms. The scale was distant 262 cms. A second solenoid was placed on the opposite side of the needle about 80 distant, and served to annul the effect of the magnetising solenoid. The current in the latter was $0.075 \times 0.195 = 3.46$ ampères, the field $= 1.257 \times 3.46 \times 114.2 = 497$ units.

The deflections produced were when the specimens were placed in the coil axis

No 1.	1.0	Moment 608.5 Vol.
2	0.05	
3	0.0	
4	0.5	
5	0	

$$M = \frac{d}{262} \times 0.18 \times \frac{(121)^3}{2} = d \times 608.5$$

No. of Sample	Weight in air	Weight in Water	Loss. or vol.	sp. g.	% assay of Fe_2O_3	% Iron	Deflection	Moment	Intensity of magnetisation	K.ot	H
1	84.27	64.85	19.42	4.34	71	51.4	1.0	608.5	31.3	0.063	497
2	26.81	17.96	8.85	3.03	16	11.6	0.05	30.4	3.435	0.0069	
3	9.025	5.97	3.055	2.95	20	14.5	0	0	—		
4	60.32	45.62	14.70	4.10	94	68.1	0.5	304	20.68	0.042	
5	64.34	46.72	17.62	3.65	1	0.7	0	0	—		

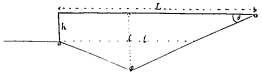
Particulars of the two Electro dynamometers

No. 1.	a	coil	# 19. BWG	D.C.C. #0.042"	9	layers	of 22	turns each.	198 turns
	b	"	# 13	" " " #0.095"	2	"	" 10	" "	20
No 2	a	"	# 23 BWG	D.S.C. 0.025"	15	"	" 36	" "	540
	b	"	# 6	D.C.C. 0.203"	1	"	" 5	" "	5

Mean Length 50 μ
" Breadth of front 4.2 μ } 7. III. 90
" Length " 5.5 μ.

Problem.

A wire is drawn taut over two small freely running but fixed pulleys and under a third intermediate free and weighted pulley in the same vertical plane. Determine the strain at any given position of the intermediate pulley when the two others are at known positions not on the same level.



(1) $\frac{W}{2} = S \sin\theta$

(2) $l = L - h\cot\theta$

(3) $\frac{2(l-h)}{l} = \tan\theta$

$\therefore \quad \frac{2(l-h)}{L - h\cot\theta} = \tan\theta \qquad \therefore \quad 2(l-h) = L\tan\theta - h$

$\therefore (2d \mp h)\sqrt{1-\sin^2\theta} = L\sin\theta$

$(2d \mp h)^2(1-\sin^2\theta) = L^2\sin^2\theta$

$\sin^2\theta\{L^2 + (2d \mp h)^2\} = (2d \mp h)^2$

$$\sin\theta = \frac{2d \mp h}{\sqrt{\{L^2 + (2d \mp h)^2\}}}$$

and $$S = \frac{W}{2}\,\frac{\sqrt{\{L^2 + (2d \mp h)^2\}}}{2d \mp h}$$

If $h = 0$ this becomes

$$S = \frac{W}{2}\,\frac{\sqrt{\left(\frac{L}{2}\right)^2 + d^2}}{d}$$

Problem.

To determine the torque of a multipolar motor of gramme type.

Let p be the number of poles.

ϕ - - flux through each polar surface. abs. meas.

c - - total current through the armature abs. m.

w - - number of wire or bars counted all round.

h - - strength of field at any point. abs.

r - - equivalent radius of polar head or of armature

b - - breadth of the armature cms.

Then at any part of the armature the $\frac{c}{p}$

The current in any angle $\Delta\theta$ of the armature is :-

$$\Delta c = \frac{\Delta\theta}{2\pi}\,\frac{wc}{p}$$

the attraction on this will be $b\,\Delta c\,h$ tangentially

The total tangential attraction round each segment of the circle will be $b\,h\,\frac{2\pi}{p}\,\frac{wc}{2\pi p} = \frac{b\,h\,wc}{p^2}$ where h is the mean field

But $\phi = b\,h\,\frac{2\pi r}{p}$

$\therefore$ attraction over each segment $= \frac{wc\phi}{2\pi p r}$

and total attraction all round circle $= \frac{wc\phi}{2\pi r}$

the moment at unit radius is thus $\frac{wc\phi}{2\pi}$ and is independent of the number of poles.

Test of a sample of overhead ~~Silicon~~ Bronze Trolley wire for the Sprague Railway Co.

This wire 100 feet in length was received at the Laboratory on the 26th inst. It was required to test it for tensile strength, ductility, conductivity, and accuracy to gauge.

To ascertain its breaking strain a short length was taken to Messrs Morton of N.Y. chain maker, but as their machine only indicates up to 2000 lbs. it became impossible to try it thus, and arrangements were made to test it at the Laboratory instead.

The wire was secured to one of the beams of the travelling crane, and a pulley was lashed opposite to the other and just beneath it. A heavy weight was lifted in the dip between these two point of support dynamometer fashion, and the weight raised by chain block and fall until the wire parted. This occurred twice following at the hauling nip at almost the same strain.

In these cases $L = 184$ $h = 13.0$ $d = 40$ (1) $W = 1866$.
39.5 (2)

$$S_1 = \frac{W}{2}\,\frac{\sqrt{184^2 + 67^2}}{67} = \frac{W}{2}\,\frac{\sqrt{33856 + 4,489}}{67} = \frac{W}{2}\,\frac{\sqrt{38,345}}{67} = \frac{W}{2} \times \frac{196}{67}$$

$$S_2 = \frac{W}{2}\,\frac{\sqrt{184^2 + 66^2}}{66} = \frac{W}{2}\,\frac{\sqrt{33,856 + 4,356}}{66} = \frac{W}{2}\,\frac{\sqrt{38,212}}{66} = \frac{W}{2} \times \frac{195.5}{66}$$

$W = 1866$ lbs $S_1 = 933 \times 2.926 = 2.73$ tons wt. $= 61,300$ lbs. per sq. in. $= 4295$ kgms per sq. cm.

$S_2 = 933 \times 2.962 = 2.764$ . . . $= 61,900$ . . . . $= 4352$ . . . .

Tests of Sprague Railroad Wire contd.

The diameter of the wire was determined by laying 78 feet along the floor and measuring with a Brown & Sharpe micrometer screw to 1/10,000" at every 3 feet. The measurements were in one or two instances checked by other micrometers of the same firm.

No. of Obs.	Measurement	Mean x	v (Z = m)	v^2	Σv^2		Σv		
1	0.2385	0.2385"	0						
2	0.2394		−0.0009	81×10^{-8}	741×10^{-8}				
3	0.2385		0				0.0101		
4	0.2386		−0.0001	1	$\sqrt{20}$				
5	0.2387		−0.0002	4					
6	0.2387		−0.0002	4	27.22×10^{-4}				
7	0.2375		+0.0010	100	$= 0.002722$				
8	0.2386		−0.0001	1					
9	0.2386		−0.0001	1					
10	0.2390		−0.0005	25	$\sigma_1 = 0.000375$		$\sigma = 0.00035$		
11	0.2380		+0.0005	25					
12	0.2379		+0.0006	36	$\sigma_2 = 0.000675$		$\sigma_m = 0.000070$		
13	0.2388		−0.0003	9					
14	0.2390		−0.0005	25					
15	0.2382		+0.0003	9					
16	0.2385		0						
17	0.2397		−0.0012	144					
18	0.2385		0						
19	0.2393		−0.0008	64					
20	0.2384		+0.0001	1					
21	0.2380		+0.0005	25					
22	0.2381		+0.0004	16					
23	0.2373		+0.0012	144					
24	0.2380		+0.0005	25					
25	0.2386		−0.0001	1					

The mean diameter of the sample was thus $0.2385'' \pm 0.000075$ (0.03%)
$= 0.6058 \pm 0.00019$

The chances are 2 to 1 that as far as observations are concerned the diameter lies between 0.2384" and 0.2386", assuming the wire to be a true cylinder. The mean area is $0.04467 5'' \pm 0.0000253$ (0.056%)
$.28826 \pm 0.0001163$ sq. cms

The conductivity was measured by passing a current of about 9 amperes through a measured length of this wire in ct. with the standard grid and 0.01 comparing the terminal p.d. by differential galvanometer. Temp of air 24°C.

1st test. R. of G. 2738 ω each coil. $\left(\begin{matrix}2744.5\\2725.5\end{matrix}\right)$

775 ω added to grid = 3519.5 ω in grid ct

Res. of wire $\frac{2728.5}{3949.5}$ grid = 0.7742 grid. = $0.7742 \times 0.04913 = 0.03804\,\omega$

The length of wire between pressure wires was 2263.5 cms.

res. per cm $= \frac{3.8044 \times 10^{-2}}{2.2635 \times 10^{3}} = 1.681 \times 10^{-5}$ per sq. cm $= 4.8445 \times 10^{-6}$

$= 4.8445$ ab. w. legt.

Pure copper $= 1620$ @ 0°C. $\quad 1620\,(1 + 0.0388 \times 24) = 1620 \times 1.0931$

$= 1771$ @ 24°

% Conductivity $= \frac{1771 \times 100}{4.8445} = 0.3655$ $\quad$ or 36.55% of Matthiessen

8·7 feet weigh 1·5 lbs = 0·17241 lbs. per foot = 910·2 lbs. per mile of 5280 ft
250·5 cmc = 650·4 gms = 2·716 gms per cmc. = 4422 gms per c.c.

Ductility Test.

Two samples ten inches long received from complete burn before breaking. = 2·5" for one burn. $\frac{260}{2.5}$ = 104·0" per inch. = 1728" per foot.

Resume of Specific Conductivity Tests

No. of Test	Length tested	Compared with	Res. of Galvo	Balance	added to	Res. with Conductivity @ 24°C	Spec. Cond. Cm (from 0°C 1771 @24)	Mean Spec. Cond.	v	t_m
1	2263·5	0·004913	2724·5 / 2705·5	775 ω	0·004913	4834·5	0·3660		0·0005	
2	2264	0·004913	2724·5 / 2705·5	775 ω	"	4836	0·3662		0·0001	
3	1500	0·004913	2724·5 / 2705·5	2870 ω	"	4825	0·3670		0·0009	
4	1500	0·009833	2735 / 2735	4275 ω	wire	4845	0·3656	0·3661	0·0005	0·00013
5	750	0·009833	2735 / 2735	760 ω	"	4830	0·3660	(4837·5 Lab)	0·0001	0·036%
6	750	0·009833	2735 / 2735	770 ω	"	4843	0·3657		0·00014	
7	586·2	0·009833	2735 / 2735	0 ω	"	4835	0·3663		0·0002	
						Mean 4837			0·0027	

The mean resistivity being 4837 legal units $= 1.678 \times 10^{-5}$ " per cm.
$= 5.114 \times 10^{-10}$ " per foot
$= 2701$ " per mile of 5280 ft

Comparison of standard 0·01 ω and grid, the former being at 25·6°C the latter at 28°C.
Res. & Temp. of standard = 0·009833 ω Res. of G. 27400 ω
10,950 ω added to grid ct. with 8 amperes through main ct.
$= \frac{13,690}{27400} \times 0.009833 = 0.04913$ ω

2nd Test. Length tested 2264 ω R. of G. 2724·5 / 2705·5 775 ω added to grid

$$R_{cc} = \frac{2705.5}{2724.5 + 775} = \frac{2705}{3499.5} \times 0.04913 = 0.773 \times 0.04913 = 0.03755 \text{ ω}$$

$$= \frac{0.037985}{2264} = 1.678 \times 10^{-5} \text{ per cm} = 4.836 \times 10^{-6} \text{ per c.c.}$$

$= 4836$ abs. l. u. per c.c.

Matthiessen's std $= 1771$ - - - @ 24°C

$= 36.62\%$ 0·3662

3rd Test length tested 1500 R. of G. 2724·5 / 2705·5 2870 added to grid

$$R_{cc} = \frac{2705.5}{2724.5 + 2870} = \frac{2705.5}{5594.5} \times 0.04913 = 0.02511$$

$$= \frac{2.511}{1.5} \times 10^{-5} = 1.674 \times 10^{-5} \text{ per cm} = 4.825 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4825} = 0.367 = 36.7\%$

4th Test. Length tested 1500 R. of G. 2735 / 2735 4275 ω added to wire (0·01 ω)

$$R_{cc} = \frac{4275 + 2735}{2735} \times 0.009833 = 2.563 \times 0.009833 = 0.02521 \text{ ω}$$

$$= \frac{2.521 \times 10^{-5}}{1.5} = 1.681 \times 10^{-5} \text{ per cm} = 4.845 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4845} = 0.3656 = 36.56\%$

5th Test. Length 750 R. of G. 2735 / 2735 760 ω added to wire (0·01 ω)

$$R_{cc} = \frac{2735 + 760}{2735} \times 0.009833 = 1.278 \times 0.009833 = 0.01257 \text{ ω}$$

$$= \frac{1.257 \times 10^{-5}}{0.75} = 1.676 \times 10^{-5} \text{ per cm.} = 4.830 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4830} = 0.366 = 36.6\%$

6th Test length another 750 R. of G. 2735 / 2735 770 ω added to wire (0·01 ω)

$$R_{cc} = \frac{2735 + 770}{2735} \times 0.009833 = 1.2815 \times 0.009833 = 0.01260 \text{ ω}$$

$$= \frac{1.260 \times 10^{-5}}{0.75} = 1.6805 \times 10^{-5} \text{ per cm} = 4.843 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4843} = 0.3657 = 36.57\%$

7th Test length 586·2 R. of G. 2735 / 2735 0·01 ω balance wire

Res of wire $= 0.009833$ ω

$$= \frac{0.009833}{586.2} = 1.678 \times 10^{-5} \text{ per cm.} = 4.835 \times 10^{-6} \text{ per c.c.}$$

Spec. Conductivity $= \frac{1771}{4835} = 36.63\%$ 0·3663

On the number of discs in a Wirt Lightning Protector to carry off a ⅝" spark.

Assuming what is true for plane parallel surfaces that the breaking voltage is 30,700 with 325 volts for polarisation.

Then a ⅝" spark $= \left(\frac{2.54}{8} \times 30{,}700 + 325\right)$ volts $= 10{,}073$ volts.

And if the thickness of each disk be d cms.

$$10{,}073 = nd \times 30{,}700 + n \times 325$$

$$\text{or } n = \frac{10{,}073}{30{,}700\, d + 325}$$

d is stated to be $0.03'' = 0.075$

$$n = \frac{10{,}073}{2300 + 325}$$

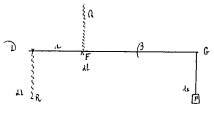
$$= 3.84 \quad \text{say } 4.$$

On the condition of ~~double~~ mixed levers.

If D F G be a lever with a force applied at P and a fulcrum at F it is of the first order. If D be the fulcrum it will be of the second order. Considering each of these points as capable of moving when sufficient force is applied to them, the condition of acting as 1st order is $Q > P + R$

and " " " " 3rd " " $R > P\frac{\alpha}{\alpha+\beta}$

It is possible however for both forces to be adjusted into capability of independent but coincident motion.



These conditions are

$$P\,ds - Q\,dl - R\,d\lambda = 0 \qquad (1)$$

$$ds - \frac{\alpha+\beta}{\alpha}\,dl - \frac{\beta}{\alpha}\,d\lambda = 0 \qquad (2)$$

Substituting the values of ds from (2) in (1)

$$P\left(\frac{\alpha+\beta}{\alpha}\right)dl + P\frac{\beta}{\alpha}\,d\lambda = Q\,dl + R\,d\lambda$$

Equating coefficients of dl & $d\lambda$

$$\therefore Q = P\left(\frac{\alpha+\beta}{\alpha}\right) \qquad R = P\frac{\beta}{\alpha}$$

$$\text{or } Q = P + R \qquad = P + P\frac{\beta}{\alpha}$$

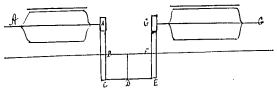
$$\text{Also } dl = \frac{ds}{2}\cdot\frac{\alpha}{\alpha+\beta} \qquad d\lambda = \frac{ds}{2}\cdot\frac{\alpha}{\beta}$$

The energy delivered is $P\frac{ds}{2}$ to Q

" " $P\frac{ds}{2}$ " R

so that while P and Q retain compatible values the energy absorbed at G will be equally divided between Q and R.

Differential bevel gear is a mixed lever. The moment of the working ~~dynamo~~ motor being M and that of the dynamo being $D = \frac{M}{\beta}$, the shaft at Q is $\frac{M}{\alpha}$ and if this be insufficient to start the car, the motor & dynamo must generate more power until ~~Q = M~~ $M = \frac{\beta Q}{\alpha}$



On the equations of motion of the differential bevel-wheel (90

Equations continued from page 77.

If ε be the emf. of constant supply at motor terminals
n_1, n_2 - - number of revs. per sec.
φ_1, φ_2 - - fluxes
r - - velocity ratio of the gears AB and GF
t - - no. of each armature
w - - no. of wires - - - .

Then the current in A is $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}$

- energy - - - $\dfrac{n_1\varphi_1^{-1}w\,(\varepsilon - n_1\varphi_1^{-1}w)}{r}$
- moment at A - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{\varphi_1 w}{2\pi}$
- - - B - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{\rho\varphi_1 w}{2\pi}$.
- pressure P_C - C - $\dfrac{\varepsilon - n_1\varphi_1^{-1}w}{r}\cdot\dfrac{r\varphi_1 w}{2\pi\rho}$ where ρ is rad: of diff. wheel
- - P_E - E - $\dfrac{\varepsilon - n_2\varphi_2^{-1}w}{r}\cdot\dfrac{r\varphi_2 w}{2\pi\rho}$

and since $P_D = P_E$ we have $\varphi_1(\varepsilon - n_1\varphi_1^{-1}w) = \varphi_2(\varepsilon - n_2\varphi_2^{-1}w)$

or if $\beta = \dfrac{\varphi_2}{\varphi_1}$ $\quad \dfrac{\varphi_2}{\varphi_1} - \beta = \dfrac{S_1}{S_2}$ where S_1 is the resistance drop in A
- S_2 - - - - - B.

the ratio of the fluxes must be in the ratio of the pickmil drops.

Pressure at D $= \dfrac{C}{\rho}$ - where C is the moment of reaction at D

$$= \frac{2(\varepsilon - n_1\varphi_1^{-1}w)}{r}\cdot\frac{r\varphi_1 w}{2\pi\rho}$$

$$\therefore\ C = \frac{2(\varepsilon - n_1\varphi_1^{-1}w)}{r}\cdot\frac{r\varphi_1 w}{2\pi}$$

$$= \frac{2\varphi_1 r\varphi_1 w}{2\pi}$$

$$= 2\times \text{torque of motor.}$$

Rough Determination of the amount of gold in a matrix of quartz.

Weight of specimen of same stone without gold :— 11.q. 210 gr = 6335 grains
less 7. 460 — 3523
2812

in water 11q 450 . 5262
less 7. 460 . 3523
1739

sp. g. = 1073 ÷ 2812 = 2.621

Weight of specimen containing gold. 3lbs. 9.sq 40 gr. = 25196
less 7 100 — 3160
22,036

in water 2 lb. 7q. 310 gr 17,372
7 100 — 3160
14212

$7814 \times 0.06448 = 506.4$

sp. g. = 22036 ÷ 7814 = 2.819

$2.621\,(506.4 - x) + 19.3\,x = 506.4 \times 2.819$
$16.679\,x = 506.4\,(2.819 - 2.621)$
$= 506.4 \times 0.198$
$= 100.3$
$x = 5.973$ c.c. $\times 19.3 = 115.3$ grs of gold
$= 4067$ oz. of gold.

Meteorological Records.

Date		Barometer Inches	Barometer Corr.	Temp.	Barometer Corrected 0° F.	Thermometer Max.	Thermometer Min.	Thermometer Rng.	Thermometer Wet	Rainfall 24 hours	Wind	Remarks
July	5th	30.050	76.32			83	55°	79	77	0.10	N.W.	Fair. Clearing
	6	29.840	75.51	76.0	29.713	86	56	78	78	—	N.	Fine
	7	29.845	75.82	78°	29.787	78°	62°	89°	77°	—	S	Fair
	8	29.733	75.53	80°	29.677	101°	60°	80°	85°	—	S	Fair
	9	29.607	75.24	82	29.457	86	75°	81°	76	—	N.W.	Fair
	10	29.847	75.84	83°	29.724	89	65°	67°	63°	—	N.W.	Fair
	11	29.947	76.07	83°	29.824	80°	56°	73°	67°	—	N.W.	Fair
	12	29.883	75.91	75°	29.734	70°	57°	78°	75°	—	S	Fair
	13	29.841	75.82	72°	29.751	89°	63°	68°	65°	.075	S.E.	Overcast. Rain
	14	29.893	75.88	70°	29.762	86°	56°	77°	70°	—	S	Fair. Overcast
	15	29.834	75.79	73°	29.710	85°	67°	83°	80°	—	S	Fair
	16	29.871	75.84	80°	29.722	76°	70°	85°	80°		W	Fair
	17	29.725	75.50	83°	29.590	88°	72°	80°	83°		S	Fair
	18	29.739	75.59	76°	29.621	78°	68°	73°	69°	.58	N.W.	Fair
	19	29.731	75.53	74°	29.605	80°	55°	75°	68°		S.W.	Fair
	20											
	21											
	22	29.895	76.09	72°	29.826	90	54	76°	70°		N.W.	Fair
	23	29.964	76.15	72°	29.894	91°	52°	75°	71°		N.W.	Fair
	24	29.871	75.88	73°	29.798	78	63	76	73°		S.W.	Overcast. Cloudy
	25	29.739	75.53	75°	29.614	78	70	73	70	.90	S.W.	Rainy
	26	29.685	75.56	74°	29.517	78	70	72	76	.295	S	Overcast
	27	29.871	75.88	70°	29.734	87	67	83°	75		S	Overcast.
	28	29.977	76.07	80°	29.833	98	67	83	79		S	Fair
	29	29.971	76.15	74°	29.831	84	68	74	72	.55	S.W.	Overcast
	30	29.893	75.93	77°	29.752	94	69	84	82	.12	S	Overcast
	31	29.785	75.56	85°	29.579	96°	75°	89°	83		S	Fair
Aug	1	29.785	75.60	89°	29.639	93°	75°	85°	83°		S.W.	Fair. Overcast.
	2	29.957	76.04	82°	29.779	90	72	83°	79°		C	Overcast
	3											
	4	29.917	76.00	80°	29.773	87	65	83°	84	.02	S	Fair
	5	29.921	76.01	82°	29.771	94°	70°	85°	82°		S	Fair. Overcast
	6	29.881	75.90	80°	29.737	87°	70°	82°	78°	.34	S.W.	Fair. Overcast
	7	29.893	75.79	79°	29.752	91°	66°	86°	75°		S.W	Fair
	8	29.867	75.75	76°	29.735	85°	68°	77°	74°		SW	Overcast
	9	29.713	75.48	72°	29.592	75°	65°	69°	68°	.07	S	Overcast Rain
	10	29.525	75.00	75°	29.396	91°	63°	82°	77°		S	Fair. Overcast
	11	29.635	75.25	70°	29.523	85°	56°	69°	64°	.04	W	Overcast
	12	29.741	75.51	70°	29.729	74°	63°	71°	68°		N.	Fair
	13	29.895	75.94	70°	29.771	75°	61°	71°	68°	.16	N	Fair. Overcast
	14	29.785	75.66	72°	29.665	80°	61°	75°	68°		SW	Fair
	15	29.957	76.09	73°	29.864	86°	60°	72°	66°		S	Fair
Omitted	16	29.992	76.05	75°	29.873	83°	65°	82°	75°		S	Fair
	17	29.960	76.10	70°	29.831	85°	69°	74°	73°	.502	W	Rainy. Clearing
	18	29.930	76.03	72°	29.810	73°	66°	71°	70°		S	Rainy. Overcast.
	19	29.886	76.01	75°	29.757	76°	69°	78°	74°	.61	W	Fair
	20											
	21	29.862	76.02	75°	29.733	82°	65°	75°	73		S	Overcast.
	22	29.712	76.07	75°	29.583	88°	65°	77°	74°	.275	S	Fair
	23	29.744	75.88	69	29.633	80°	58°	65°	64		S	Fair
	24	29.826	75.91	63°	29.791	66°	49°	65°	65°			Overcast.
	25	29.820	75.85	67°	29.715	74°	47°	70°	64°			Fair
	26	29.728	75.58	77°	29.633	77°	60°	76°	73°			Fair
	27	29.526	75.03	74°	29.400	79°	69°	67°	72°	.950	S	Rainy
	28	29.750	76.02	74°	29.624	84°	60	71°	68			Overcast.
	29	29.721	75.85	74°	29.595	79°	61	79	72°		NW	Fair
	30	29.588	75.7	74°	29.462	79°	61°	73°	68°	.12	N	Fair
	31	29.735	75.71	66°	29.667	94°	54	65	63		SW	Fair
Sept	1	30.065	76.31	65°	29.952	70	54°	67°	64°		S	Fair
	2	30.091	76.31	70°	29.929	85	61	81	67°		N.W.	Fair
	3	29.989	76.18	74°	29.860	87	67	79	70		S.W.	Fair
	4	29.987	76.18	75°	29.860	85°	61	77	73		S	Fair. Overcast
	5	29.809	75.98	76°	29.737	85°	65°	72°	74°			Fair. Overcast
	6	29.829	75.79	78°	29.691	90	62	82	79		S	Overcast
	7	29.877	75.90	76°	29.785	84	69	78	75	.005	NE	Overcast
	8	29.963	76.09	75°	29.732	84	63	75	72		NE	Overcast
	9	29.933	76.08	70°	29.804	78	63	77	74		SE	Fair
	10	30.045	76.32	70°	29.931	81	65	65	64	.01	N	Overcast
	11	30.017	76.35	66°	29.906	67	59	63	63	.035	NE	Rainy.
	12	29.893	75.71	69°	29.776	77	63	74	73	.35	S.W.	Rainy

1	3290 × 400 ÷ 14 =	93,700	= 950 say	1000	0	3.46 =	16,270
2	2280 × 250 ÷ 14 =	103,500	= 1050		- -		16,270
3	1050 × 185 ÷ 14 =	13,900	= 150	150	1.00		1,575
4	460 × 400 ÷ 14 =	13,150	= 125	150			690
5	460 × 110 ÷ 14 =	36,15	= 40	150			690
6	2890 × 50 ÷ 14 =	103,300	= 110	150			4,650
7	1730 × 1150 ÷ 14 =	142,100					
7a	1500 × 750 ÷ 14 =	80,300	= 880	900	$ 4.30		6,450
7b	1730 × 400 ÷ 14 =	49,400	= 550	500	$ 2.91		5,100
8	1770 × 570 ÷ 14 =	72,100	= 800	800	$ 4.00		7,400
9	1115 × 730 ÷ 14 =	58,150	= 640	650	$ 3.24		3,610
10	3150 × 400 ÷ 14 =	90000	= 1000	1000	$ 4.96		15,570
11	2620 × 175 ÷ 14 =	32,740	= 330	350	$ 2.32		6,080
12	2360 × 500 ÷ 14 =	84,300	= 450	900	$ 4.20		10,150
13	3870 × 170 ÷ 14 =	47,000	= 500	500	$ 2.80		10,840
							104,840

Provisional and Rough Determination of a Conducting 3-wire system for Copenhagen Denmark

Specified basis :— Voltage at lamp not to exceed 110.
Pressure Fall in mains " " " 1·4 volts on one side
" " feeders " " " 1·4 " " "
Density of current in conductors " " 200 amp. per sq. cm.
Current in each lamp represented as 0·55 amp.

This means 3·78 Watt per mc. cp.

We have therefore P.D. at lamp 110 110 = 220
" " service 111·5 111·5 = 223
" " junction 112·9 112·9 = 225·8
" " bus bars 126·9 126·9 = 253·8

The mains marked on the chart amount to 19600 metres 64,300 feet.

Provisionally we may assume 13 feeding points and 9 main feeders as follows. There are 21,000 lights on the canvas.

No. of feeder	Position of Bifurcation	Position of Junction	Length on map.	Length in metres	Length in feet.	Lamps supplied	Current supplied	Feeder required.	Report at last price.
1			36 {14, 14}	720 {280, 280}	2360 {920, 920}	1590	400	950 say 1000 amp.	
2						1925	450	1050	
3			16	320	1050	743	185	150	
4			7	140	460	1609	400	150	
5			7	140	460	450	110	150	
6			44	880	2890	200	50	150	
7			15 {11.5, 12}	300 {230, 240}	980 {750, 790}	4576	7(a) 750, (b) 400	7(a) 900, (b) 550	
8						2276	570	(c) 800	
9			17	340	1115	2935	730	650	
10			~~48~~	~~960~~	~~3150~~	1594	400	1000	
10a			~~59~~	~~1180~~	~~2890~~ 2870	681	170	500	
11									
12			25 {15, 11}	500 {300, 220}	1640 {980, 720}	707	175	350	
						1964	500	900	
						21,025	5250		

On the Resistance of Mr Insulls House Mains.

A test of the cable on the 7th July, made the insulation about 10Ω of each conductor. The line is composed of

3 #6 B.W.G. overhead wire each 8800 feet. @ 2.5×10^{-6} = 0·875Ω each
3 #67 E.S.C. cable - - 1050 - @ 1.7×10^{-6} = 0·185Ω.
14,500 ft. Total res: 1·060Ω.

With 50 lamps lit the current would be 12·5 ∫ and the fall of potential in the line 13·25 volts.

Wheatstone bridge measurement of the lines made each 1·225Ω to the meter from the dynamo room.

Res: of Gahon: wire 5385·3 ÷ 2 = 2692·6 ω @ 22·3°C.
integrally 5391 ÷ 2 = 2695·5 recalled.

Barometer Reading 76·00 temp. 66°F Temp. of air at sealing 19·7°C.

Measurement of distances between grooves in the Brashear plane grating. G. III. 90

With 0·001" lines on glass the micrometer distances were

#1.	1001
2	993
3	1005
4	993
5	1012
6	1003
7	1000
8	1000
9	995
10	990
	9991

Mean 999.1 say 1000

10 distances between grooves = 6·75 micrometer revs.
1 " = 0·675 " "
= 0·675 of 0·0001" = 0·0000675"
= 6.75×10^{-5}"
= 14815 to the inch.

The instrument = 14438 " " by engraving.

Discrepancy 3% +

Entry of Conductivity Coefficient for copper with temperature
Test taken by Kennelly + Felsenden 24th April 1890.

This was done experiment on the effect of cooling the bulb instead of heating it. Gasolene & ether were formed round the bulb while air was pumped through. The experiment was spoiled after a certain temperature was obtained by the inrush of an bubble. These were supposed to have been imprisoned between the mercury and the rubber tube. They never interfered while the pressure acted outwards but were drawn in as the pressure acted inwards. The results ought to be reliable however up to the time of first bubbling.

No of Obs	Time	Temp Room Bath	Obsd. res of a th. $\gamma_{\alpha\theta}$	Obsd. res of tre.	Obsd. res of arc.	Ratio of change	Calibration Reading	Res: of Hg.	Temp. of Hg. column	Coeff. of Expn for Hg.	Corrected res of Hg @ 0°C.	Coeff γ
1	21·16	18·6 19·1	10·580	10·530	20·7140		33.268		19.8			
2	·35		·323	·316	·3145		31·628					
			10·257	10·214	20·4285							
3	·50						29.4444					
4	·54	18·5 19·6					26·948		19·8			
5	22·00						24·104					
6	·12						22·911					
7	·15	18·5 19·1	Unreliable.				20·7442		19·6			

This bubble first escaped between these readings.

No of Obs	$(V-1)(\theta+\theta_0)$	Corrected Thermometer at room temp.	Corrected at temp at Obs.	Temp. °C by air thermo.	Res. at obs. for balance	Res: in Gahon at	Res. of wire Gahon at	Ratio.	Ratio of res: wire	Coeff. first	Res for Cell. when put	Ratio
1					14·03 (4)						13·.	
2					13·25 (3)							
3					12·25 (1)							
4					10·75 (3)							
5					8·80 (3)							
6					8·22 (3)							
7					6·74 (1)							

General Mathematical Theory of lighting large areas of cities by electricity considered from an economical standpoint.

3-wire system.

Let d be the drop in volts abs. emf. units permitted in the main
" δ " " " " " " " feeders (full load)
" R " " rad: " cms: of the circular areas lighted
" b " " breadth " " " each block (centre to centre)
" λ " " number of lamps operated in each block at full load.
" γ " " current required for each lamp in abs units.
" ρ " " resistivity of copper in the conductors . . .
" r " " radius of conductor " cms.
" σ " " specific gravity " " " ~~per cc~~
" w " " weight per cm: of main.
" ϖ " " " " " feeder
" W " " total " of copper in mains
" Ω " " " " " " " feeders.
" Γ " " " current.

Then $\because$ the area of the district is $4R^2$, and the area of one block is b^2 there are $\frac{4R^2}{b^2}$ blocks and $\frac{4R^2}{b^2}\lambda$ lamps.

$$\Gamma = \frac{2R^2}{b^2}\frac{\lambda}{2}\gamma = \frac{A\lambda\gamma}{2b^2}$$

Each block requires $4b$ of main. Total length of main is

$$\mathcal{L} = \frac{4R^2}{b^2}\times 4b = \frac{16\pi R^2}{b}$$

The weight of main is such that $d = \frac{\gamma}{2}\frac{\lambda}{4}\cdot b\frac{\rho}{\pi r^2}$

$$\text{and } w = \sigma\pi r^2$$

$$\therefore d = \frac{\rho\lambda b\sigma}{8w}$$

$$\therefore w = \frac{\rho\lambda b\sigma}{8d}$$

$$W = 4\frac{4R^2\rho\lambda\sigma}{2d} = \frac{2R^2\rho\lambda\sigma}{d} = \frac{A\rho\lambda\sigma}{2d}$$

Each feeder supplies 2 blocks. The ~~weight~~ feeders for the first tier are such that

$$\frac{2\lambda}{2}\cdot\frac{\gamma}{2}\cdot\frac{2b\rho}{\pi r^2} = \delta$$

$$\text{and } \varpi_1 = \sigma\pi r^2$$

$$\therefore \frac{2\lambda\gamma b\rho\sigma}{\varpi_1} = \delta$$

$$\therefore \varpi_1 = \frac{2\lambda\gamma b\rho\sigma}{\delta}$$

the weight of these feeders $= \frac{4b^2\lambda\gamma\rho\sigma}{\delta} = p$ say.

Total Weight of 1st tier $= 4p$.
" " " 2nd " $= 8 \cdot 2 \cdot 2p$
" " " 3rd " $= 12 \cdot 3 \cdot 3p$
" " " nth " $= 4n \cdot n \cdot np$.

Aggregate $= 4n^2p = 4\left(\frac{R}{b}\right)^2 p$

$$= \left\{\frac{R}{b}\left(\frac{R}{b}+1\right)\right\}^2 p$$

$$= \frac{R^4}{b^2}p \text{ approximately.}$$

$$= \frac{4R^4\lambda\gamma\rho\sigma}{b^2\delta}$$

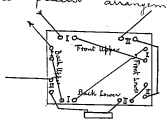
$$= \frac{A^2\lambda\gamma\rho\sigma}{b^2\delta} = \frac{2A\Gamma\rho\sigma}{\delta}$$

$$= A^2\cdot\frac{\lambda}{b^2}\cdot\frac{\Gamma\rho\sigma}{\delta}$$

The total weight of main is thus directly proportional to the area concerned, feeders proportional to the square of the area and the density of illumination.

"Differential Astatic Galvanometer

One of the coils of this instrument having developed a partial disconnection near the bottom end, had to be rewound with 0.002" copper wire. This done the instrument had a resistance of about 13,500ω including a compensating coil and 3ω balanced the two sides for resistance after a fine differential balance for current had been obtained. The present arrangement of circuits is:—



When balanced for resistance a change of 1ω in the res: of either side with 5 volts produces a deflection of 114 divs.
1 " would produce 2.8 " thus 6,750ω
1 ampere " " 18,900 divs. " 18,900ω.

On the most convenient values of the inductance of a pair of parallel cylindrical wires (infinitely long) and remote from magnetic material.

The Maxwell formula is $\underset{(\text{per cm})}{L} = 2\mu\log_e\frac{b^2}{a_1 a_2} + \frac{1}{2}\mu$

$$= 4\log_e N$$

where $\mu = 1$ and N is the ratio of the perpendicular interaxial distance to the common radius of the wire

$$L = \underline{9.212\log_{10} N}$$

If a pair of wires be separated by an interaxial length of 5 diameters, and be each 11 miles long, their inductance will be about 100 metres.

The error introduced into the result by a discrepancy in the measurement is inversely as N.

Formulae for calculating the Inductance of Coils

Perry gives (Electr. Engr 2/6/30 p 211)

n = number of turns
a = mean rad: of winding (cm)
b : axial length
c = axial depth of winding
$b + c < \frac{a}{2}$

Hollow cylindrical coils

$$L \text{ microhenries} = \frac{n^2 a^2 \times 10^{-7}}{1.8444\,a + 3.1\,c + 3.5\,b}$$

$$\frac{L}{R} = \frac{V \times 10^{-3}}{0.728\,a + 1.33\,c + 1.5\,b}$$

For a single circular loop Otto Blathy gives

$$L \text{ (cms)} = 4\pi R \left\{ \log_e \frac{4R - r + \sqrt{16R^2 - 8Rr}}{r} + \frac{16}{15}\frac{R^2}{r^2} - \left(\frac{16}{15}\frac{R^2}{r^2} + \frac{4R}{15r} + \frac{8}{5}\right)\sqrt{1 - \frac{r}{2R}} \right\}$$

or approximately $= 4\pi R \left\{ 0.57944 + \log_e \frac{R}{r} - \frac{2r}{R} - \frac{r^2}{28R^2} - \frac{r^3}{48R^3} - \cdots \right\}$

R = rad: of loop r = rad: of wire in cms.

Tests of a certain asbestos-cement tested for the Sprague Electric Railroad Co.

This cement is made up in 5 lb tins marked as H.W. Johns asbestos retort cement. It sets readily in dry air and rapidly under the influence of heat. The microscope does not indicate the presence of any metallic particles, nor does analysis show any free metal. It is white and pasty. It is supposed to contain potassium or sodium silicate probably the latter.

Two hundred light old pattern meter plates were set at the usual distance in their hard rubber clamps and the spaces between them filled with cement. This was set on the cylinder plate of the engine at a temp. of about 300° F to dry. It hardened superficially round the edges, but after 30 hours a lamp could be lit almost to fill up through the mass, and on forcing the plates apart, the interior was found to be quite soft and pasty.

A test was made of some silicate of soda in the form of a rough right circular cylinder with plane surfaces. Diam. 2.6 length 1.95 gave when tested by bridge a resistance of 1.500 ω say 3.500 ω and 2000 ω with 5 volts 1000/1000 say 5.3 eq. cond. area so that the spec. res. = $\frac{2000}{1.95} \times 5.3 = 5.730$ ω. Using 120 volts and the Siemens tan. galv. a varying deflection of about 45° was obtained from which the resistance would be only 900 ω or 255 ω per c.c.

Tests of the Inductance of a coil and adjustable induction standard the property of Mr Winningham

These were two double coils, the outer one fixed vertically and the inner revolving on a vertical axis passing symmetrically through the outer. About 40 turns of silk covered copper wire are supposed to be wound on each coil. A special meter bridge was employed to test measure the inductance in the belief that it would be too small to measure by secohmmeter but it was found necessary to employ the secohmmeter finally.

No of Obs	Rod. measured	Degree indicator by pointer	Resc.	Bridge	Condenser f	Inductance Hitmeter	Inductance coil	Inductance of standard
1	Standard	0°	3.422	1000/100	0.015	5.133		
2		45°	3.424	-	0.022	7.532		
3		90°	-	.	0.030	10.272		
4		180°	-	-	0.045	15.410		
5	Standard + coil	0°	4.789	-	0.023	11.024	5.893	5.833
6		90°	4.785	-	0.034	16.279	6.0	
7		180°	4.782	-	0.045	21.520	6.11	
8	Coil	—	1.425	-	0.0405	5.771	5.771	
9								

By direct test found the coil to be almost exactly equal to the standard at minimum (0.80°) and the standard min. = −80° of our standard.

Inductance measurements.

Five turns of S.S.C. wire diam. were wound fairly close to one another round a drum of 435·25 cms. circumference. The inductance of these 5 turns compared with the standard coil at minimum position was $\frac{20.4}{79.6}$ .. The same 5 turns were then compared with the inductance of two wires laid on the floor, hard copper 0·041" (0·1041) diam and 17·5 cms apart 12,00 in length. The inductance of this loop would be

$$\frac{17.5}{0.0521} = 336.5 \quad \log = 2.526999 \quad \text{say } 2.53$$

$$9.212 \times 2.53 = 23.3 + 0.5 = 23.8$$

$$12,00 \times 23.8 = 28,560 \text{ cms.}$$

The ratio of this inductance to the 5 turns on the drum was

$$\frac{17.9}{82.1}$$

So that the standard coil at minimum 90° has :-

$$2.856 \times 10^{7} \times \frac{82.1}{17.9} \times \frac{79.6}{20.4}$$

$$2.856 \times 10^{7} \times 4.587 \times 3.903$$

$$2.856 \times 10^{7} \times 17.9$$

$$5.112 \times 10^{5} = 5.112 \text{ kilometres.}$$

The two specially prepared flat leads about 300 long leading to the parallel wires must have had some inductance, say ~~2~~ ×300 = 2800 = 30,500 cms, in which case the standard minimum = 5·46 kilometres.

The inductance of one standard mutual induction coils was measured directly by secohmeter as follows:-

No. of Coil.	Temp B.	Ratio	Res.	Condenser	Inductance Kilometre	Indicated on coil
1	25·3°	10,000/100	2·032	0·0254	5·08	−90°
2		"	2·038	0·048	9·78	0°
3		"	2·038	0·075	15·29	+90°

Comparison of two Standard Legal Ohm coils, one the original Elliott's Standard Legal Ohm no 202, the other the new Elliott Standard checked at Cambridge, no 229 just received here.

22nd July 1890.

Differential Galvanometer Balanced. Res: 13.570 – both coils T.B. 23°C 100%/100. 5w added to one side for res. balance.

Two standards were connected in series, and copper wire wound round their electrodes were led off to the galvanometer. No deflection was obtained the coils balancing. The temp. of no 202 was 23.4°C that of No. 229 22.75°C by #1 thermometer. The balance was repeated later in the evening and found perfect when the temp. of each was 23.75°C.

On the Resistance per mile of 5280 feet that Silicon Bronze Trolley wire should offer in order to meet a specified conductivity.

The resistivity of hard drawn pure copper at zero = 1620 L. units
" @ 75°F = 24°C this would be 1771 " "

a diameter of 0.238" = 0.0141488 sq in = 0.2870" cms.

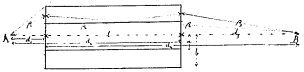
the res: per cm: of pure wire of this diam = 617.97 units
" " " mile of 160,933 cms " " " " = $1.609 \times 6.17 \times 10^{5}$
= 9.923×10^{5} L. units
= 0.09931 Legal ohms

From this we have the following table.

% Cond.	Ohms per mile	% Cond.	Ohms per 1760 yd mile	% Cond.	Ohms per mile	% Cond.	Ohms per mile	% Cond.	Ohms per mile
100	0.993	70	1.419	60	1.655	50	1.986	40	2.483
90	1.103	69	1.439	59	1.683	49	2.027	39	2.545
80	1.241	68	1.460	58	1.712	48	2.068	38	2.612
70	1.419	67	1.483	57	1.741	47	2.113	37	2.683
60	1.655	66	1.504	56	1.773	46	2.159	36	2.758
50	1.986	65	1.527	55	1.806	45	2.207	35	2.838
40	2.483	64	1.552	54	1.839	44	2.257	34	2.920
30	3.310	63	1.576	53	1.874	43	2.310	33	3.009
		62	1.602	52	1.909	42	2.364	32	3.103
		61	1.628	51	1.948	41	2.422	31	3.203.

On the Difference of Magnetic Potential at definite points on the axis of a solenoidal coil, due to the circulation of a given current strength.

Let A & B be the selected points



Let a be the internal radius of the coil
b - - external " " " "
l - its length
c - - mean radius $\frac{a+b}{2}$
ρ - the distances of c from A $= (d_1^2 + c^2)^{\frac{1}{2}}$
ρ_2 - - - - - - " " $= (d_2^2 + c^2)^{\frac{1}{2}}$
β - - - - - - - B $= (d_3^2 + c^2)^{\frac{1}{2}}$
β_2 - - " " " " " $= (d_4^2 + c^2)^{\frac{1}{2}}$
ΔV - - difference of potential between A & B
γ - - current in the coil
N - - total number of turns
n - - number of turns per cm. $= N/l$

Then $$\Delta V = 4\pi n\gamma\left[l - \tfrac{1}{2}\{(\rho_1 - d_1) - (\rho_2 - d_2) + (\beta_1 - d_3) - (\beta_2 - d_4)\}\right] \quad (1)$$

Let $\rho_1 = \beta_1$

Then $$\Delta V = 4\pi n\gamma\left[l - \tfrac{1}{2}\{(\rho_1 - d_1) - (\rho_2 - d_2)\}\right]$$

$$= 4\pi n\gamma\left[l - (\rho_1 - \rho_2) - l\right]$$

$$= 4\pi n\gamma\left[\rho_2 - \rho_1\right] \quad \text{or} \quad 4\pi N\gamma\left(\frac{\rho_2 - \rho_1}{l}\right) \quad (2)$$

If $d_1 = 0$

Then $$\Delta V = 4\pi n\gamma\left\{\sqrt{l^2 + c^2} - c\right\} \quad (3)$$

Let l be very great compared with c

Then $$\Delta V = 4\pi n\gamma l$$

$$= 4\pi N\gamma. \quad (4)$$

On the amount of Rotation produced in the plane of a circularly polarised beam of D light by a plain coil of copper wire wound on a tube of CS_2.

Let e be the current in the wire in abs. electromagnetic units
ε - - e.m.f. on the coil " " " "
r - - res: of - - - - - -
k - - coiling space - - - - - - c.c.
l - - length of - - - - - - cms.
a - - inner rad: - - - - - -
b - - outer - - - - - - -
n - - number of turns
v - - difference of magnetic potential between ends of coil.
θ - - rotation in degrees
φ - - constant of rotation in degrees.
s - - sectional area of coiling space at at angles to axis
d - - diameter of wire
t - - thickness of insulating coat.

Then $$\theta = v\varphi = 4\pi e\varphi n \text{ to a first approximation} \quad (5)$$

$$= \frac{4\pi\varepsilon n\varphi}{r} \quad (6)$$

$$n = \frac{l(b-a)}{(d+2t)^2} \quad (7)$$

$$r = \frac{4\pi k}{\pi d^2 (d+2t)^2} \quad \text{see book II p. 21.} \quad (8)$$

$$\theta = \frac{4\pi^2 e\varphi l (b-a) d^2}{4\rho k} \quad \text{but } k = \pi(b^2-a^2)l \quad (9)$$

$$= \frac{\pi^2\varepsilon\varphi d^2}{(b+a)\rho} \quad \text{where } \varphi = 6.67\times10^{-6},\ \rho = 1.7\times10^{3} \quad (10)$$

If $\varepsilon = 10^8$ $$\theta = \frac{1.2\pi\theta\times10^2 d^2}{(b+a)} \quad (11)$$

This gives the maximum rotation in terms of d, b, and a.

If h be the heat permissable in ergs per sec: per sq cm: of surface

Then see Book II p 136 $$h = \frac{e^2 D^2 d^2}{8\pi b l^2 \rho (b^2-a^2)} \quad (12)$$

Substituting this value of d in the above we have

$$\theta \doteq (d+2t) = \pi l\sqrt{\frac{8\varphi b h (b-a)}{\varepsilon}} \quad (13)$$

and $$\theta = \cancel{\pi l}\,\chi\left(\frac{\pi\varepsilon\varphi}{(b+a)\rho}\right)\left(-t \pm \sqrt{t^2 + \frac{\sqrt{\chi}}{\varepsilon}}\right)^2 \quad (14)$$

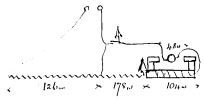
where $$\chi = 8\pi b l^2 \rho h (b^2 - a^2) \quad (15)$$

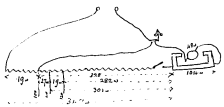
and this gives the rotation possible for a given e.m.f. in terms of the known constants and the dimensions of the coil, to a first approximation.

If λ be the correction for the magnetic length of the coil as obtained from (2), (10) becomes

$$\theta = \frac{\pi\varepsilon\varphi d^2 (l-\lambda)}{(b+a)\rho l} \quad (16)$$

where $$d = -t \pm \sqrt{t^2 \pm \tfrac{l}{\varepsilon}\sqrt{8h\pi b\rho(b^2-a^2)}} \quad (17)$$





Tests of new model series-wound electric light phonograph motor 1st August 1820.

Resistances fixed in the circuit 0·010" gauge	126ω	
- under control of governor - -		178ω
- of field magnets	104ω	
- - armature	48ω	
Res: of machine stopped	278	
- - - when governor lifts		456ω

When cylinder held, and 120 volts on mt. the observed current = 0·089 ebach 0·457 amp. or 29·26 Stdt. ϱ. = 0·428 amp

$\frac{120}{456}$ = 0·263 amp + $\frac{120}{278}$ = 0·432 amp.

When chipping rapidly the current was about 0·42 amp.
- - at 100 revs per min - - - - 0·44 -
- - running light - - - 0·321 to 0·33 amp.

Machine well under control, and generally self starting.

After running on 120 volt pressure for 6 hours, the temp. of the air was 32°C that in the top of the res: was 37·°C, and in the phonograph base 37·5°C.

At 200 revs per min, the current observed was: 0·344

$\frac{120 - x}{278}$ = 0·344 x = 24·4 or 0·122 volts for each revolution per minute

Tests of amended pattern 25th August 1820

The brushes of this machine being altered to the lever type necessitated a readjustment of resistances. as follows

	120 volt	110 volt	100 volt
Field	104ω	104ω	104ω
Armature	48ω	48ω	48ω
Res. permanently in cct.	68ω	46ω	19ω
- under control of governor	282ω	301ω	328ω
	499ω	499ω	499ω

When running at ordinary speed, whether chipping, recording or reproducing the average current is (23·5 Stdt) 0·32 amp. and when held from running (33·Stdt) 0·49 amp.

After remaining in cct. for one hour unrested the temp. rose to 31°C.

For a still later amendment see entry for 3rd Sept page 111

1st–2nd August.

Test of Carrying Capacity of New Standard Edison Meters from Bergmann & Co.

The meters tested were :–

2 # 8 s	one 3-wire	one 2-wire
2 # 4 s	" " "	" " "
2 # 2 s	" " "	" " "
2 # 1 s	" " "	" " "

These were all joined up to lamp banks of 650 lamps in all, each meter taking its full load.

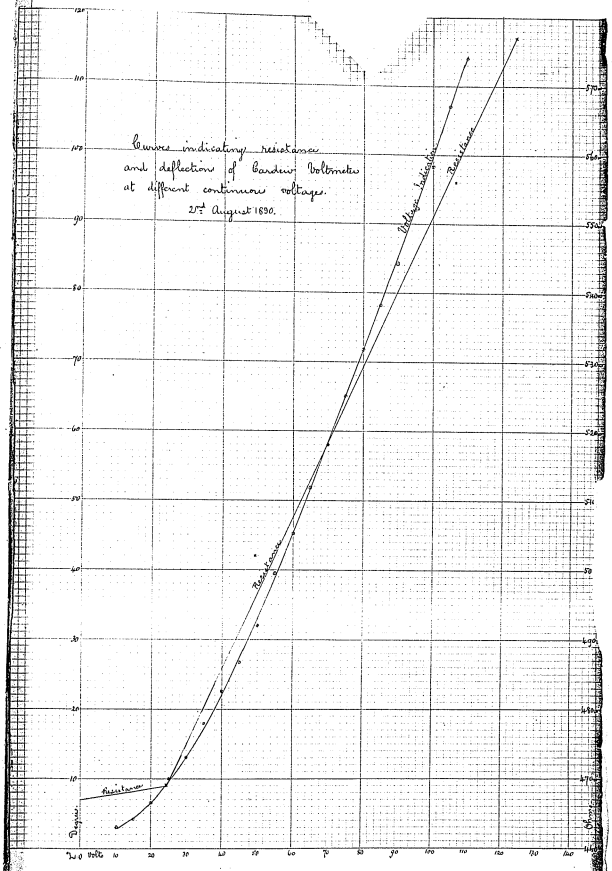
After running for 3 hours the temperatures at the top inside the meter were :– air 33° C.

Meter	# 1 2-wire	# 1 3-wire	# 2 2-wire	# 2 3-wire	# 4 2-wire	# 4 3-wire	# 8 2-wire	# 8 3-wire
Temp. observed	46.4	46.8	45.1	53.5	56	64.4	60.5	63
Rise above air.	8.4	13.8	12.1	20.5	23	31.4	27.5	30.

The last five temperature elevations being considered excessive, long slots pointing 45° downwards were cut horizontally in the backs of the meters, as near the top as possible one slot to each meter, so that the ventilating arrangements now consist of :– a row of 45° pointed holes near the bottom of each shunt, and a ½" slot near the top. The test was then continued until 24 hours had expired with following final temperatures :–

	Meter	# 1 2-wire	# 1 3-wire	# 2 2-wire	# 2 3-wire	# 4 2-wire	# 4 3-wire	# 8 2-wire	# 8 3-wire
Temp. at top	Temp.	38	43.2	43	46.8	49	53	53.8	54.5
	Elevation	8	13.2	13	16.8	19	23	23.8	24.5
	Temp. air 33.0								
Temp. at base	Temp.	30	30.4	32	34.6	34.6	34.2	34.8	34
	Elevation	0	0.4	2	4.6	4.6	4.2	4.8	4

Internal temps.


Curves indicating resistance
and deflection of Bardwell Voltmeter
at different continuous voltages.
25th August 1890.
Voltmeter Deflection
Resistance
Resistance
Resistance
Volts
Ohms

Calibration of Cardew Voltmeter for high potentials.

The resistance of the voltmeter by bridge = 467 ω @ 30°C.

When on 118. volts, the current = 0·0241 Obach = 0·2114 = 552 ω

" - 100·2 - - - = 0·036 - = 0·1875 = 534 ω

- - 124 - - - = 15°55' Std = 0·2165 = 577 ω

- - 106·5 - - - = 14°15' = 0·1965 = 556 ω

- - 49·2 - - - = 7°25' = 0·0981 = 502 ω

- - 24·2 - - - = 3°55' = 0·0516 = 469 ω.

The resistance of the instrument therefore varies with the indication. The resistance used in circuit with the machine consisted of german silver wire wound to 30 ohms doubly on 13 frames of wood, the whole being soaked in molten paraffine wax. This resistance possesses negligible inductance, and has four coils as follow.

	No. 1	500 ω
@ 29°C.	" 2	1032 ω
	" 3	1996 ω
	" 4	4750 ω

Tested up to 1200 volts.

The Cardew was calibrated by comparison with a Weston Voltmeter almost correct in its indications:-

Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind.	Volts per $\frac{\Delta v}{\Delta D}$	Volts	°Ind	$\frac{\Delta v}{\Delta D}$
10	3	8·3	45	26·8	1·05	80	71·8	0·80	115	122	2·
15	4·2	4·1	50	32	0·66	85	78·1	0·82	117	122·8	
20	6·5	2·2	55	39·5	0·87	90	84·2	0·64			
25	10	1·4	60	45·2	0·76	95	92	0·8			
30	13	1·7	65	51·9	0·7	100	98·3	0·57			
35	17·9	1·0	70	58	0·7	105	107	0·7			
40	22·5	1·1	75	65	0·73	110	114	0·63			
		1·1									

On the effect produced by the insertion of an inductance l in a previously inductionless simple sine alternating circuit of emf E frequency p and resistance r.

The current previous to insertion will be $c = E\sin pt/r$

after insertion it will be $c = \frac{E}{r}\sin pt - \frac{l}{r}\frac{dc}{dt}$ $\qquad p = 2\pi n$

$$\text{or} \quad T\frac{dc}{dt} + c = \frac{E}{r}\sin pt$$

$$\frac{dc}{dt} + \frac{c}{T} = \frac{E}{l}\sin pt$$

$$\therefore \quad c = \varepsilon^{-\int\frac{dt}{T}}\left(\int\left(\varepsilon^{\int\frac{dt}{T}}\frac{E}{l}\sin pt\right)dt + \kappa\right)$$

$$= \varepsilon^{-\frac{t}{T}}\frac{E}{l}\int\left(\varepsilon^{\frac{t}{T}}\sin pt\right)dt$$

$$= \varepsilon^{-\frac{t}{T}}\frac{E}{l}\left\{\frac{\varepsilon^{\frac{t}{T}}\left(\frac{\sin pt}{T} - p\cos pt\right)T^2}{p^2T^2+1}\right\}$$

$$= \frac{E}{l}\left\{\frac{\sqrt{\frac{1}{T^2}+p^2}\left\{\sin(pt-\theta)\right\}T^2}{T^2\left(p^2+\frac{1}{T^2}\right)}\right\}$$

$$= \frac{E}{l}\,\frac{\sin(pt-\theta)}{\sqrt{\frac{1}{T^2}+p^2}}$$

$$= \frac{E}{r}\,\frac{\sin(pt-\theta)r}{\sqrt{r^2+p^2l^2}}$$

$$= \frac{E}{\sqrt{r^2+p^2l^2}}\sin(pt-\theta)$$

where $\theta = \tan^{-1} pT$ or $\tan^{-1}\frac{pl}{r}$

Problem:– A resistance r having an inductance l is connected in series with a condenser of capacity k and a periodic emf a simple harmonic function of the time, determine the permittance of the condenser which shall annul the self induction

Let v be the instantaneous p.d. on the pair so that on the condenser

Then $v - u = l\frac{dc}{dt} + cr$

$$v = E\sin pt$$

$$u = e\sin(pt-\theta)$$

$$c = k\frac{dv}{dt} = pEk\cos(pt-\theta)$$

$$\therefore \quad E\sin pt = E\sin(pt-\theta) + pekr\cos(pt-\theta) - lkep^2\sin(pt-\theta)$$

$$= E\left\{\sin(pt-\theta)(1-lkp^2) + pkr\cos(pt-\theta)\right\}$$

$$= E\sqrt{(1-lkp^2)^2 + p^2k^2r^2}\cdot\sin(pt-\theta+\phi)$$

When $l=0$ and $k=\infty$ $c_{max} = \frac{E}{r}$

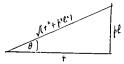
under present conditions $c_{max} = k\frac{dv}{dt} = kEp\frac{E}{\sqrt{(1-lkp^2)^2+p^2k^2r^2}}$

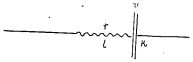
$$\therefore \quad p^2k^2r^2 = (1-lkp^2)^2 + p^2k^2r^2$$

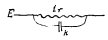
$$\text{and} \quad p = \frac{1}{\sqrt{lk}}$$

$$\text{or} \quad \sqrt{k} = \frac{1}{p\sqrt{l}}$$

$$k = \frac{1}{p^2l}$$







Let $e = E\sin pt$

$$q = \frac{E\sin(pt-\tan^{-1}pT)}{p\sqrt{(1-p^2T^2)}}$$

$$c_k = k\frac{de}{dt} = kpE\cos pt.$$

$$c_l + c_k = \frac{E\sin pt}{r}$$

$$\therefore \quad \frac{E}{r}\sin pt = \frac{E}{r}\frac{\sin(pt-\tan^{-1}pT)}{\sqrt{1-p^2T^2}} + kpE\cos pt.$$

$$\frac{\sin pt}{r} = \frac{\sin(pt-\tan^{-1}pT)}{r\sqrt{1-p^2T^2}} + kp\cos pt.$$

$$k = \left(\frac{\sin pt}{r} - \frac{\sin(pt-\tan^{-1}pT)}{r\sqrt{1-p^2T^2}}\right) \div p\cos pt$$

$$= \frac{1}{pr}\left\{\tan pt - \frac{\sin pt - \tan^{-1}pT}{\cos pt(\sqrt{1-p^2T^2})}\right\}$$

Amplitude of Main Current
Line of Short Circuit
Line of Open Circuit
Reactances per phase.
Volts Amp.

Test of Small Meter Motor whose design is recorded on pages 74-75. August 4th 1890.

The instrument has a vertical steel shaft and runs on centers. There are 18 segments on the commutator ring. Armature each wound in two layers of 21 turns = 756 which in all of drawn 0.
The resistance of the armature and its connections = 0.34 ω.
Fields are wound with silk covered copper wire diam.
The resistance of the left hand field = 3980 ω
" " " right " " = 3290 ω.
The instrument was connected up to a sample #1 Meter 3-wire with its two strips in series through a piece of copper wire. A little more than double the standard pressure is therefore supplied to the motor. The following observations were taken with the dial recording.

No. of Obs.	Lamps in ckt.	Pressure on mains Volts	Ohmeter Reading in Main ckt.	Amperes in Lamp ckt.	P.D. at Motor terminals.	Revs. per min. of motor		e.m.f. generated by motor	Resistance in motor ckt.	Energy consumed by motor.
1	1	109.5	0.11	0.564	0.062	11.75				
2	2	109.5	0.195	1.00	0.128	45				
3	3	109.5	0.297	1.523	0.200	75	30			
4	4	107	0.395	2.026	0.270	113	38			
5	6	107	0.602	3.088	0.420	174	61			
6	8	107	0.787	4.037	0.554	235	61			
7	10	106.8	1.000	5.128	0.712	300	65			
8	12	106.8	1.175	6.026	0.834	349	49			
9	14	107.5	1.370	7.026	0.980	400	51			
10	16	107.5	1.550	7.950	1.110	447	47			
11	18	107.5	1.710	8.770	1.224	482	35			
12	20	108	1.920	9.846	1.374	534	52			
13	20		1.92	9.846		618	One field coil			
14	20		1.92	9.846		616	Both	in series		
15	20	107.5	1.92 Shunts in series	9.846		536	Both	multiple		
16	20	107.5	0.285 Armature series	1.462	1.270	510	0.783		1.462	0.255 1.145 generated 1.4 Pot. absorbed
17	20	106	0.285	1.462	1.276	680	0.783		1.462	
18	1	108.5	0.03 Armature series to field position	0.154	0.06	8.75			0.154	0.0092 Watt absorbed
19	1	108	0.03	0.154	0.06	8.25			0.154	

The motor generates 0.00153 volt for each revs. made per minute
" " and 0.0918 volt " " " " " second.

The starting current is seen to be 0.4 amp. producing a p.d. at armature terminals of 0.0512 volt: This would cause a current of

$$\frac{0.0512}{0.31} = 0.165 \text{ ?} \therefore c = 0.0165, \quad w = 756$$

$$\varphi c w = 10^8 \times 1.53 \times 10^{-3} \times 60 = 1.53 \times 10^5 \times 60$$

$$\varphi = 60 \times 1530 \times 10^3 / 756 = 12{,}140$$

$$\frac{\varphi c w}{2\pi} = \frac{1.2140 \times 10^4 \times 1.65 \times 10^{-2} \times 0.756 \times 10^3}{0.62932 \times 10^1} = 2.410 \times 10^4 \text{ dyne cm.}$$

The starting torque for this motor was thus about 25 gm. cms.

Test of Motor-Meter when running in reverse direction. Fans curved back. 19th Aug. 30.

Connections same as in last test

No. of Trial	Number of lamps	Block	Current in Main cct. amperes	P.D. on Shunt	Approx. no. of Shunt	Speed of motor revs per min	P.D. on mains		
1	1	0·100	0·505	0·05		5	128 v.		
2	2	0·210	1·061	0·126		43			
3	4	0·462	2·333	0·396		127			
4	6	0·700	3·536	0·460		211			
5	8	0·905	4·572	0·600		288			
6	10	1·155	5·833	0·774		382			
7	12	1·360	6·870	0·910	1·325	462			
8	14	1·550	7·830	1·0444	0·133	530			
9	16	1·760	9·02	1·200		615			
10	18	1·960	10·06	1·298		655			
11	20	2·100	10·77	1·398	0·13 "	765			

The removal of the glass cover from the instrument when running at full speed was found to reduce the speed about 70 revs per min, and this effect was repeated on several occasions.

Six tubes of prepared paper intended for underground conductors were received from the Interior Conduit Co. on the 21st Aug. They were all left submerged in the tank on roof same day to soak, in order to give their insulating properties a thorough test.

On the test iron wire winding for the field magnets of the motor meter. The resistances of the core has to be say 5000 ohms each and the coiling space 180 c.c. on each magnet. $\rho = 12000 = 1.2 \times 10^{4}$

$$\frac{180}{5000} = \frac{18.0 \times 10^{1}}{5.0 \times 10^{3}} = 3.6 \times 10^{-3}$$

$$d = -t \pm \sqrt{t^2 + 3.568 \times 10^{-5} \times 1.1 \times 10^{2} \times 1.19}$$

$$\pm \sqrt{7.457 \times 10^{-3} + t^2}$$

0.00746

74.6×10^{-4}

8.64×10^{-2}

0.06644 cm.

$= 0.0344" - 0.002$

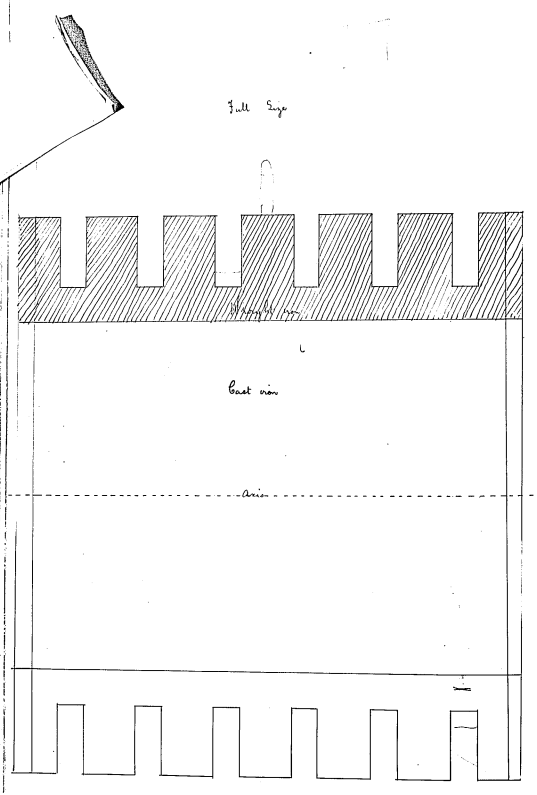
$= 0.032"$

$$= -t + 0.06654 \sqrt[6]{\frac{180}{5000}} = 0.06654 \sqrt[6]{3.6 \times 10^{-2}}$$

$$+ 0.06654 \sqrt{1.899 \times 10^{-1}} = 0.06654 \times \sqrt{18.99 \times 10^{-2}} =$$

$$+ 0.06654 \times 4.358 \times 10^{-1} \quad 0.02885 = 0.0330" - 0.002 = 0.0310"$$

$= 3.1$ mc.



On the dimensions necessary for a magnetic pulley to drive a car axle from an armature shaft.

Let the attraction due to magnetism between pulley & bar be 70 lbs per sq. in. of cross section, and the peripheral velocity of the armature pulley = v = feet per second.

n = be the ratio of the first gear
d = " " diameter of the armature pulley
D = nd " " " " intermediate "
h = one side of the bar.
θ = angle of embrace in this case assumed at 180°
P = pull in lbs. weight transmitted
p = pressure of each bar on the pulley.

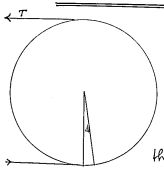
Then $\frac{\pi d}{2a} \times \frac{2}{3}$ = the number of bars in contact
$70a^2$ = p = pressure on each bar in lbs. wt.
$14a^2$ = f the plane surface resistance to slipping in lbs. wt.
$14ad$ = F " " " " " " of all the bars.
$40P$ = 40×550 = 22,000 ft lbs. per sec.
v = πd = 30
F = 730 lbs weight
$14ad$ = 730
ad = 52

With a pulley having an 8" face and provided with 6 grooves with an external diameter of 8", and bars ⅜" square, the face of the drum should be $2 \times \frac{3}{16}$" = $\frac{3}{8}$" with ⅜" for winding = 3/16" say 1¼". 6 × 1¼ = 7½" − ⅜" = 6⅞".
If the grooves have a depth of 1", the winding space will be ⅜" × 1". The cross section of the bars is 0.91 sq. cms, and at 14,000 lbs per sq. cm, the normal pull = $\frac{p}{sg}$ = grammes per sq. cm.

$$\frac{0.98 \times 1.96 \times 10^6}{25 \times 1000} = \frac{1.8 \times 10^6}{2.5 \times 10^4} \text{ grammes} = 7.2 \times 10^3 = 7.2 \text{ kgm}$$

= 45.2 kgms for each bar = 9 kgms traction per bar on a plane surface. With 2 bars to the inch, the pull is $2 \times \frac{8}{3} \times \frac{\pi}{2} \times 9$ = 225 kgms pull on a plane surface.

Mathematical theory of magnetic belt transmission.



Let t be the tension on the belt at any point
θ - - angle of embrace
r - - rad: of pulley
m - - magnetic pressure per radian (dyne)
p - - total pressure at any point . . .
μ - - coefficient of friction.

Then at any small increment of angle $d\theta$ the tangential forces satisfy the relation

$$(t + dt)\cos d\theta = t + \mu p\, d\theta$$

and the normal forces

$$p\, d\theta = 2t \sin \frac{d\theta}{2} + m\, d\theta$$

$$\text{or } p = t + m$$

$$\text{and } dt = \mu (t + m)\, d\theta$$

so that

$$\frac{dt}{t+m} = \mu\, d\theta$$

and

$$\int_T^t \frac{dt}{t+m} = \mu \int_0^\theta d\theta$$

$$\log_e \frac{t+m}{T+m} = \mu\theta$$

$$\text{or } t + m = \varepsilon^{\mu\theta}(T + m)$$

$$t = T\varepsilon^{\mu\theta} + m(\varepsilon^{\mu\theta} - 1)$$

In a belt whose weight would be negligible

$$T = m(\varepsilon^{\mu\theta} - 1)$$

Next consider a discontinuous belt of n bars angle ϕ

$$T_1 = T\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_2 = T_1\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_3 = T_2\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

$$T_n = T_{n-1}\varepsilon^{\mu\phi} + m(\varepsilon^{\mu\phi} - 1)$$

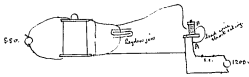
$$T_n = T\varepsilon^{n\mu\phi} + m(\varepsilon^{n\mu\phi} - 1) \quad \text{approximately.}$$

In practice the arc of embrace is at least π and $\mu = 0.2$ which $n\phi$ = at least 2

$$\therefore \quad T_n = T\varepsilon^{0.4\pi} + m \times 0.5$$

so that neglecting weight $m = 2T_n$

or the magnetic pressure per radian must be double the pull to be transmitted.



Test of seven Wirt lightning-protectors received from Harrison N.J. 21st August. 1890.

An induction coil, whose secondary is fully described on page 58 was excited by the Z machine at about 5·5 volts p.d. The terminals of the secondary were led to a battery of 6 Leyden jars of some 14 cms. int: diam., and 18 cms inside mean depth. The thickness of the glass being estimated at 0·2. This gives an area of 154 sq. cms. for the base and 792 sq. cms. on the sides = 946 sq. cms. in all for one jar = 5700 sq. cms. for the battery and a capacity of $\frac{5700}{1257} \times 1{\cdot}7$ = 4310 abs. e.s.u. $= \frac{4310 \times 10}{9 \times 10^{10}} = 480 \times 10^{-5} = 0{\cdot}0048$ microfarads.

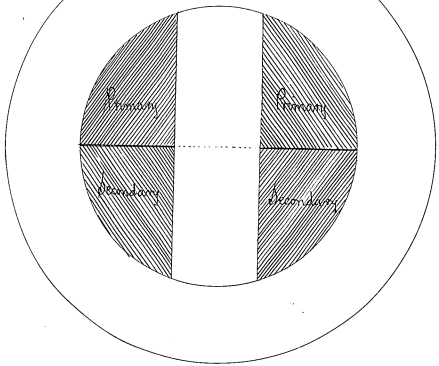
The spark produced by their discharge between two very slightly convex surfaces was 0·8 cms long equivalent to 26,400 volts. the discharging quantity $26{,}400 \times 0{\cdot}0048 = 2{\cdot}64 \times 10^{4} \times 4{\cdot}8 \times 10^{-3} = 12{\cdot}65 \times 10^{-1} = 126{\cdot}8$ microcoulombs (Check 88 abs. e.s. emf. × 4310 = 379,400 abs. qu. e.s. $= \frac{3{\cdot}794 \times 10^{5}}{3{\cdot}0 \times 10^{10}} = 1{\cdot}265 \times 10^{-5}$ = abs. e.m.u. $= 1{\cdot}265 \times 10^{-4}$ coulomb = 126·5 microcoulomb.)

This discharge was produced over the surfaces of the protectors, and the particulars of these are shewn below. The municipal dynamo generating about 1200 volts was connected direct with the terminal of the lightning protector through a safety catch, and plate after plate cut out, until the dynamo ceased followed the Leyden jar discharge.

No. of Test.	Number of Protector	Diameter of Number.	Length mm plates	Number of Plates	Material of Plates	Number of washers mm which differed	Number of washers mm which mm 2nd not differ	Number of washers mm which dynamo ceased		
1	#25	1 7/8"	5 5/8"	47	Brass	3	4	–		
2	15	"	3 1/8	29	"	3	4	2		
3	15.B	"	"	"	"	3	4	–		
4	6 A	1 7/8"	1 5/8	15	Copper	4	5	–		
5	6 B	1 7/8"	1 5/8	15	Brass	3	4	–		
6	4 A	1 7/8	1 1/4	10	"	3	4	–		
7	4 B	1 7/8	1 1/4	10	–	3	4	–		

Instrument packed with the screws still left on the metal and returned to Harrison N.J. The internal insulation was not perfect although the surface was cleaned with a hot towel, but it was sufficiently good for all requirements. The defect was known because when the discharging point was presented at A it would sometimes not precipitate an arc but would immediately do so when presented to B.

Full size cross section.



Description and Data of the first Edison Transformer completed 22nd August 1820.

This was built to compare with the Westinghouse #2 whose description is given on page 10.

The primary coil is of # 22 B.+S. 0·644, 2 lbs. 12 oz = 1247 gms. 1247
has 15 layers (58, 58, 58, 58, 57, 57, 55, 55, 52, 50, 48, 46, 46, 44, 41, 40) and 768 turns.
and a res: of 22·5 ω approx.

The secondary coil is of # 8 B.+S. 0·128", 3 lbs. 7 oz = 1560 gms. 1560
has 6 layers (8, 7, 6, 6, 5, 3) = 35 turns.

The interior core weighs 8 lbs 10½ oz = 3927
" exterior " " 31 " 13 " = 14430
Frame 726
Total 21890

External diameter over iron 15·65 } 2·78 = thickness of shell.
Int " " " 10·1 } Area 192·3 − 80·1 = 112·2
Length over " 20·4 } Vol: 112·2 × 20·4 = 2289 cc.
" coils 27.

Breadth of interior core 3·15 vol: 668 = 668 ..
Total vol: 2957 ..

Total weight of iron 18360 ~~Spf. Gr.~~ Sp. g. 6·21

Connected this & the West: transformer in parallel with the bipolar alternator making some 1500 revs. per min or 25 ~ per sec. at 1000 volts p.d. the transformer primaries overheated owing to the small frequency, so that it became necessary to reduce the pot to some 300. The Edison transformer became ~~[illegible]~~ the hotter. At 300 volts (270 max) the two secondaries were taken alternately to a noninductive circuit with a dynamometer in it. The mean deflection with the W. transformer the 1st + leads was 80° = 8·3 × 0·9 = 7·47 amp. mean, and with the E. transformer was 65° = 7·48 × 0·9 = 6·73 = 90% of the W. result. The mean e.m.f. in the secondary cct: would only be 10 to 12 volts.

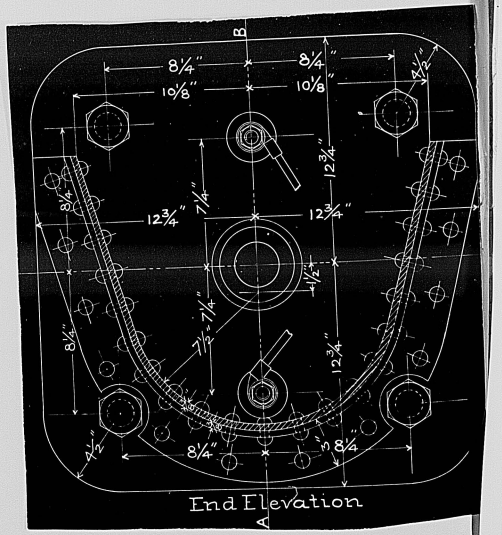
To double the pressure of the supplied secondary current it is necessary to employ twice as many turns. The diam: of the present covered is 0·154" and a wire of half that area = 0·109" = 0·083" copper = # 14 B.W.G. or # 12 B.+S. 70 turns

On the 2nd September another test was obtained using the 1200-volt Siemens alternator. The speed of the machine was not taken but the converter note was identified with 3 flat or 42·5 = 106 ~ per sec.

The secondary terminals of each machine were led to a bank of 53 100-volt lamps in succession, the primaries being permanently in circuit, and the following readings obtained on dynamometer

	App.	amp.	Mean	App.	amp.	Mean	App.	Mean	
West:	75°30'	8·06	7254	71°	7·8	702	76°40'	8·1	729 } after half an hour, the West: min, and the
Edi:	66°15	7·6	6·84	62·15'	7·4	666	64°15'	7·4	666 } Ed: primary) coil were hotter.
			94·3%			94·8%		91·3%	

Mean 93·5%



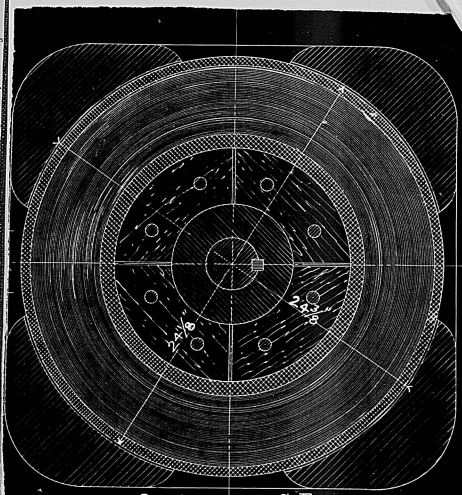
End Elevation

Memoranda

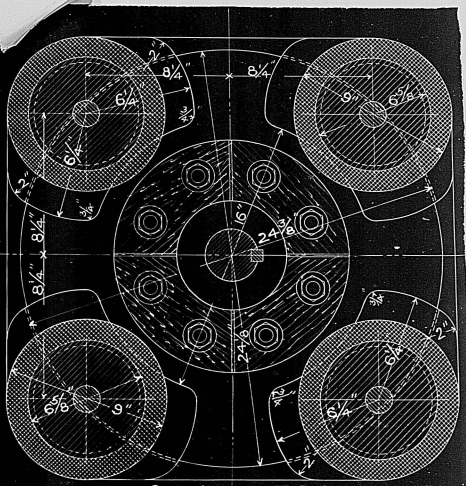
5.50 ~~cubic~~ inches per lbs of winding space
0.18 lbs . cubic inch . . .

Double-cotton covering on armature wire .005" - 0.0075" ...
Single - . .. magnet - 0.008" - 0.012" ..

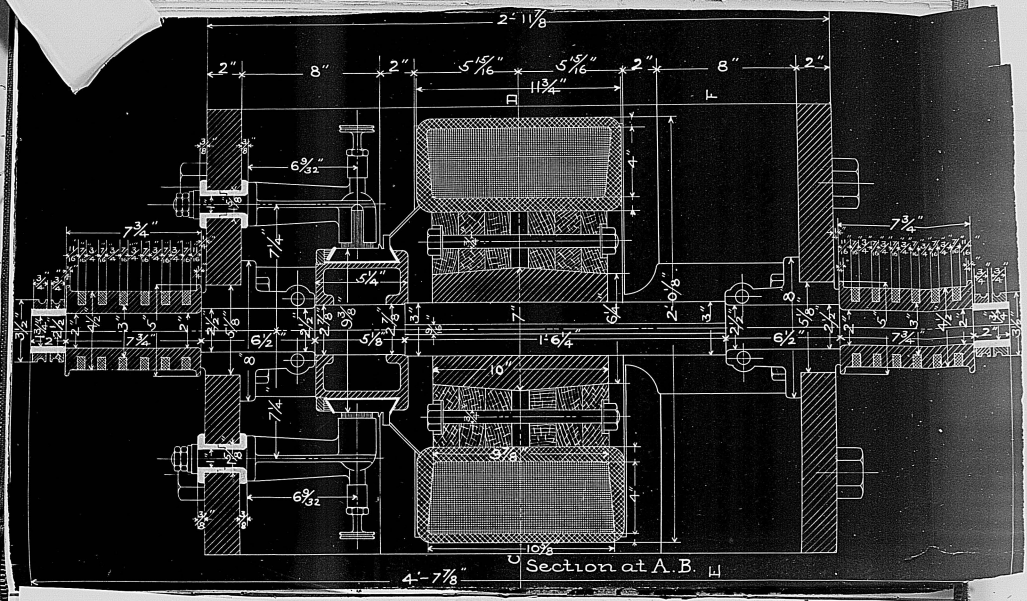
N.B. The brushes in this motor are indicated at 180°. Their true position should be at 90°



Section at C.D.



Section at E.F.


2'-11 1/8"
2"
8"
2"
5 15/16"
5 15/16"
2"
8"
2"
11 3/4"
A
L
6 9/32"
7 3/4"
7 1/4"
5 1/4"
2'-0 1/8"
1'-6 1/4"
6 1/2"
5 1/8"
10"
5 7/8"
10 7/8"
4'-7 7/8"
Section at A.B.

Data of a quadripolar tram motor to drive a 7½ ton car (loaded) 4 miles per hour up a 12 % grade.

Voltage at M.T. 500. Work required to be done at car axle = 22 HP or 30 HP allowing for loss in gearing. = 22.5 kwts and at 90% eff. = 25 kwts = 50 amperes absorbed at full load.

Torque. 1950 lbs. at periphery of wheel = 2,440 lbs. on 24" wheel = 488 lbs. at periphery of armature.

Speed 700 revs. per min. @ 12 miles per hr. = 132 revs. of wheel per min.
233 . . @ 4 . . . = 44 . . . . .
3.89 . . sec @ 4 . . . = 0.73 . . . . .

Diam. of armature 24" over all. circ. = 75.4" = 6.29' = 4400 feet per min at full speed 4 1470 feet per min. @ 4 m. per hr.

Flux: Useful flux 4,180,000 and with r = 1.6
Total flux 6,688,000 through each polar head.

Density in armature 8000 – pressed iron
. . core 15,500 – wrought iron
. . keeper 15,500 – " "

Armature Dimensions

External diameter	23⅛"	= 58.72
Depth	4"	= 10.15
Internal "	15⅛"	= 38.4
Mean breadth	10.1"	= 25.65
External "	10 5/8"	= 28.24
Internal "	9⅞"	= 25.08

Area of cut: circle 2711 } area of annulus 1555
. . int. " 1156 } Cross section 40.5 257
Volume of armature 399,635 c.c.
Sp. g. 4.9 Mass = 1950 kgms = 4400 lbs.

Wire $3.89^{n} \times 3072^{w} \times 4.18^{g} \times 10^{6} = 500 \times 10^{9}$

3072 wire all round
4 layers of 768 (of 192 in a segment)
1/32" between each block of 6.
#16 B.W.G. 0.065" = 0.080" cond = 4,225 cmil.
Armature body insulation 1/32" Clearance 1/8" Entifer 1.68 cm
Mean turn 31"
Total length 7930'
Resistance 19.8 ω in series = 1.24 ω in multiple = 1.33 ω bt. Drop at full load 67 volts.
Weight of wire on armature 110 lbs.
Torque at full load (15 lbs per amp. at periphery) = 750 lbs

Cores Wrought iron 215 sq cms 33.3 sq. in. = 16.55 cm 6⅝" diam.
Length 8" 20.3 cms = 43.650 c.c. × 7.8 = 340.5 kgms
= 75 lbs each or 600 lbs. in all.

Armature weight Iron wire 430 lbs.

copper	110
Commutator	75
Shaft	75
Wood	50
Shell	60
	800

Magnetic circuit.

Air space 1.68

Area of pole face, one side. $2 \times 260 = 520$
on surface 770 f 1290

½ of pole surface = 322

Iron keepers 30 cm. area 108 sq. cm. $\mu = 300$ $\mathcal{R} = 15{,}500$

Cores 21 - each area 108 . . $\mu = 300$. = 15,500

Pole heads exact iron

Air	$\frac{1.7}{322}$	=	0.0056
Cores	$\frac{42}{107.5 \times 300}$	=	0.0011
Keepers	$\frac{30}{107.5 \times 300}$	=	0.0011
Pole heads		=	0.0010
Total		=	0.0088

$1.257\ A.T. = 0.0088 \times 1{,}672{,}000$

$A.T. = 11{,}700$ or 5,850 per spool

Allowing for armature effect = 7000 " .

With 12.50 Watts lost in field = 2.5 amperes = 200 ω in field = 25 ω per spool. Mean turn = 2' = 5600' = 2800' = 224' per spool ω = # 18 B.W.G. 0.044 g" = 0.057" cond. = 1.69 lbs per ω = 42 lbs per spool = 336 lbs. on all.

42 lbs × 5.5 = 232 c.i. 8" = 9" ext. diam.

Belt pulleys—

Two pulleys 4.5" diam: six grooves in each ⅜" × ⅜" deep
10 # 11 B.W.G. wire 0.120" = 0.135" cond. in each groove = 60 turns per pulley = 60 feet

Two pulleys 24" diam: two grooves in each 10 wires in each groove 1" deep = 60 feet in each pulley.

240 feet of wire in all four pulleys = 0.25 ω 625 Watts at 5/8 load
120 - - #11 wire - two clutches = 0.13 ω Total 950

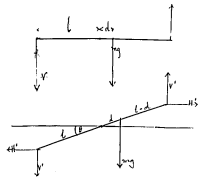
Measurement after building.

Res: of the armature between brushes measured = 1.15 ω cold say 18°C.
" " each core 25 ω 22 layers of 112 turns = 2464 turns in all.
" " all 8 in series 200 ω.
" "

Inductance of field magnets.

From the measurements recorded on page 126, $\varphi = 1.99 \times 10^6$ per core with 2.25 amperes = 8.842×10^5 lines per ampere. There are 2464×10^3 turns per core so that 2.179×10^9 lines are linked with the circuit in each core = 17432 quadrants for all 8 magnetic cores.
The resistance being 200 ω, the normal time constant = 0.087 second.
The electrokinetic momentum with 2.5 amperes is 3.922×10^3 abs. units = 39.22 lbs.
" " energy 4.41×10^8 = 44.1 Joules.
" total quantity discharged on short circuit = 2.25 × 0.087 = 0.196 coulomb.

On the mathematical relations between the dip of the magnetic ore needle and the magnetic components producing that dip



Let H be the horizontal component at locality of balancing
V . . vertical .
H' . . horizontal . . . testing
V' . . vertical . . . . .
$2l$ . . lengths of the needle between mg & d
d . . distance of center of inertia from axis
m . . mass of the needle
θ . . angle of dip
p . . strength of one pole

Then $2lVp - dmg = 0$ (1)

$2lVp\cos\theta - dmg\cos\theta - 2lpH'\sin\theta = 0$ (2)

$2lV'p\cos\theta - 2lVp\cos\theta - 2lpH'\sin\theta = 0$

$V'\frac{p}{p} - V - H'\tan\theta = 0$

$V' = V + H'\tan\theta$ (3)

If then a dipping needle be loaded by a balance weight at a locality where the vertical intensity is known then at some other locality let the true dip (unloaded) ϕ

$H'\tan\phi = V'$

and the dip loaded $= \theta$

Then $V' = \dfrac{V}{1 - \tan\theta\cot\phi}$ (4)

and $H' = \dfrac{V\cot\phi}{1 - \tan\theta\cot\phi}$ (5)

also I' the intensity $I' = \dfrac{V\operatorname{cosec}\phi}{1 - \tan\theta\cot\phi}$ (6)

$1.1 \times 0.333 \times 10^{-15} \times 10^{8} = 0.3663 \times 10^{-7}$ abs. qu.

118 dis $= 3.663 \times 10^{-8}$ " "

1 dis $= 3.105 \times 10^{-10}$ " "

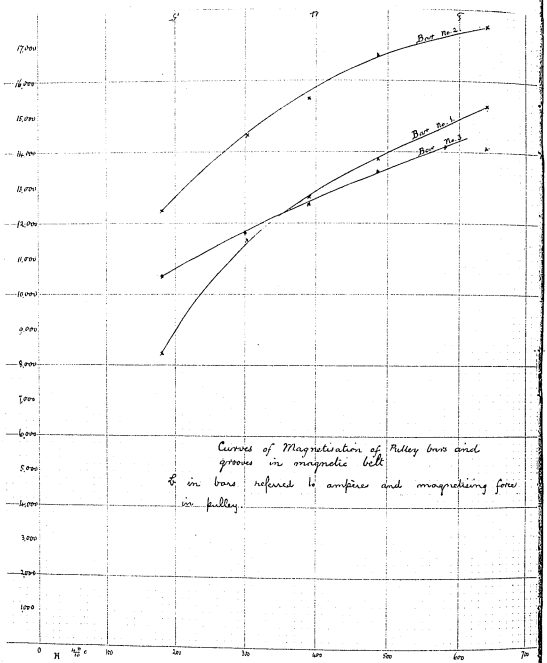
$d \times 3.105 = q^{n}$

$\frac{4}{12} \times 6.5 \times 10^{12} = q.5.418 \times 10^{11} = q$

$\frac{9}{12} \times 17.5 \times 10^{12} = q.1.458 \times 10^{12}$ "

$6.45 \times 0.25 = 1.61$

$H = \frac{2\pi}{10} \times 8 \times$ ampères $= 10 \times$ ampères for each groove.



Curves of Magnetisation of Pulley bars and grooves in magnetic belt

B in bars reduced to ampères and magnetising force in pulley

Measurements of the Magnetic Induction through the bars of the magnetic belt resting on the pulley of the car motor

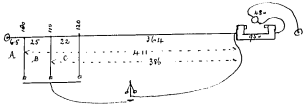
The pulley diameter was 4·5" and its face was 7½" as shewn on the blue-print facing p. 110. The bars were 7" long and ½" × ⅛" so that their cross section was ⅛ sq. in. They were ground to the curvature of the pulley on one face, and were threaded on seven composite steel wire rack-ends of 1000 lbs breaking stress each. The space between consecutive bars was about ⅛". A wire was wrapped round each one bar once to each groove and taken to a galvanometer while a measured current passed through the pulley wire. This was # 11 B.W.G. 0·12" 48 turns in all 8 per groove in 4 layers deep and two wires broad. Three bars were measured. No 1. was found to be slightly bent and to be out of complete contact with the pulley. No 2. was in good contact, and No. 3 was a bar of annealed iron. Pulley and bars were both wrought iron. The following table shews the results which are only approximate as the galvanometer was not ballistic, i.e. &c.

No. of Obs	No. of bars	Current in Pulley amperes	Throw Mean	$\frac{4\pi n}{10}$	q.	φ	B in sq. cm. section of bar	Throw for 5Ω. Nimrod with 0·3337	Values of 1 div. in quantity	Number of linkages.	No. of G.
1	1	64	146·5	2	4·568 × 10	24,640	15,300	118	3·105 × 10⁻¹⁰	6	6,500
2	2	62	168·0	2	5·216	28,260	17,560			× 2 for reversal.	
3	1	48·5	132		4·099	22,210	13,800				
4	2	49	160		4·967	26,910	16,710				
5	1	39	122		3·788	20,520	12,750				
6	2	39	148·5		4·610	24,970	15,510				
7	1	30·3	110·5		3·43	18,580	11,540				
8	2	30	138·5		4·30	23,300	14,470				
9	1	18	80		2·48	13,440	8,350				
10	2	18	118·5		3·679	19,920	12,380				
11	3	18	100·5		3·120	16,900	10,500				
12	3	32	112·5		3·49	18,900	11,740				
13	3	40	120		3·73	20,210	12,550				
14	3	50	129		4·00	21,670	13,460				
15	3	58	135		4·19	22,700	14,100				
			45 (11,000 in int.)		1·397	20,360					

The pulley at 50 ampères sustained on the belt a pull of 275 lb weight without slipping with 9 bars and an angle of 100° (50° of contact)

for 200 ampères T lbs $= 275 \left(\frac{E^{\frac{\mu 100\pi}{180}} - 1}{E^{\frac{\mu 100\pi}{180}} - 1} \right) = 275 \times 2{\cdot}66 = 730$ lbs.

allowing for the assistance of initial weight and tension the pull may perhaps be 900 lbs on each pulley.

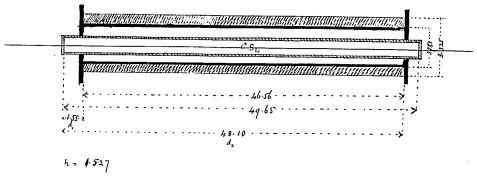


Measurement of Resistances of New Model Phonograph 3rd Sept. 20 (110 volt).

	Set for 100 volts	Set for 110 volts	Set for 120 volts.
Res: permanently in circuit	6·5 ω	31·5 ω	53·5 ω
" of field	9·5	9·5	9·5
" " armature	4·8	4·8	4·8
" " machine governor down	149·5	174·5	196·5
" under control of governor	4·11	3·86	3·64
" of circuit governor up	561·5	561·5	561·5

Two battery machines were tested. They differed only in the boring of the polar face circle. No 1. had the usual clearance. No. 2. was bored about $\frac{1}{32}$" larger on a side and so had about $\frac{1}{32}$nd. inch more clearance. The same body was used on each in turn. The current required to drive No 1. ~~reproducing~~ but not chipping was (79°·30') 2·~~785~~ amp that to drive No 2 at same speed (109 revs of cylinder per min) ·75° 2·814 amp = 9·5% more current.

27th Jany 92, a trial was made at the Phono: Works of a coil of 52 ω q.s. same size as usual for the res A (0.012" wire) and a 16 cp. lamp under control of governor without any play switch or resistances B, C. This arrangement worked satisfactorily and adopted as standard at 120 volts.



Experiments with an Optical Voltmeter

The helix was formed of No 30 B.W.G. 0.012" ·00048 covered with silk to 0.015" ·00581 in 8 layers of approximately 1200 turns each on a brass tube 4.6.56 between flanges and 2.781 in diam. (1.095"). The external diameter over the wire being 1.309" 3.325. The resistance of the helix was about 205ω @ 19°C.

The tube containing the CS_2 was of glass 49.65 long and 0.685" (1.74 cat. 0.463" (1.175) internal diameter. It was closed by 2 polished glass disks about 0.2 thick.

Test made 3rd Sept. 90.

The resistance of the coil at about 19°C was 203.4ω. It was filled with CS_2 and placed in the polarimeter. Two sodium burners were used. The coil was connected directly with the mains through a rheostat, the P.D. on the mains being 129.0 volts approx. by Wirt Voltmeter. The following observations were then made.

No. of Obs.	P.D.	Res.	Current	Rotation Minutes	Weight	Mean.	v	v^2	fv^2		Result
1	129	203.4	0.6343	+310	2		0.9	0.81	1.62	0.1231	313.6'
2				−318	2		5.4	29.16	58.32	× 13.24	± 1.63/2
3				+314.5	2					= 1.63	
4			0.625	−306	2	627.1/2	6.6	43.56	87.12		= 313.6 ± 0.8
5				+324	2		2.9	8.41	16.82		
6				−302	1		1.1	1.21	1.82		
7				Two mins. +324	1						
8	129	209.5	0.6158	−300	1		3.1	9.61	9.61		
9									17.231		

Marcant gives 0.04.15' as the constant for D in CS_2

To the first approximation therefore

$$\theta = 0.04.15' \times 1.257 \times 9600 \times 0.625$$
$$= 4.15' \times 1.257 \times 0.96 \times 6.25 \times 10'$$
$$= 313'$$

To find the terminal length correction h = 1.53

$$d_1 = 1.55 \qquad \rho_1 = \sqrt{\{(1.55)^2 + (1.53)^2\}} = \sqrt{(2.4025 + 2.3409)}$$
$$= \sqrt{(4.7434)} = 2.18$$

$$d_2 = 48.10 \qquad \rho_2 = \sqrt{\{(48.1)^2 + (1.53)^2\}} = \sqrt{(2313.6 + 2.34)}$$
$$= \sqrt{(2315.94)} = 48.12$$

$$\rho_2 - \rho_1 = 45.94$$

corrected $$\theta = \frac{313 \times 45.94}{46.56} = 308.9$$

The surface of the coil was 46.6 × 3.14 × 3.53 = 516.5 sq. cm.

energy developed per sec = 129 × 0.625 = 80.6 Joules

= 6.41 sq. cm per Watt.

Formula (9) becomes on simplification ($\rho = 1.7\times10^{-6}$ $\sigma = 8.95$)

$$\theta = \frac{2.5772}{10.67}\times10^{2}\,\varphi\sqrt{\frac{l\,m\,h}{a}}\cdot\frac{\pi}{1+X} \qquad (11)$$

For the D line φ is stated to be 4.15×10^{-2} by Mascart

$$\theta = \frac{1.607}{1.067}\times10^{5}\sqrt{\frac{l\,m\,h}{a}}\;\frac{X}{1+X} \quad \text{where } X = \sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}},$$

$$\theta = \frac{1.607}{10.67}\sqrt{\frac{l}{a}\,m\,h}\;\frac{X}{1+X} \qquad (12)$$

When used for intermittent and measuring currents h may be put $= 0.02$

$$\theta = \frac{1.607}{1.518}\sqrt{\frac{l}{a}\,m\,h}\times\frac{X}{1+X} \qquad (13)$$

When used for steady currents h may be put $= 0.01$

$$\theta = \frac{1.607}{1.067}\sqrt{\frac{l}{a}\,m}\times\frac{X}{1+X} \qquad (14)$$

The limit of $\sqrt{\frac{l}{a}}$ is probably 10 that of the fraction 1 and hence with 10 kgms. of wire, the limiting rotation is by (14)

$$\frac{1.607}{1.067} = 1.5 = 17^\circ.47'$$

In the experiment recorded on the preceding page, $h = 0.156$

$l = 46.56$, $a = 1.39$ $m = 565$ $X = 1.225$

So that $\theta = \frac{2.07}{10.67}\times\sqrt{\frac{46.56\times565\times0.156}{1.39}}\times\frac{1.225}{2.225}$

$$= \frac{1.607\times54.34\times1.225}{2.225}$$

$$= 31^\circ.5$$

When the heat limit cannot be reached owing to resistance in circuit so that $c = \frac{E}{\beta+r}$, these formulae do not hold. In such a case

Diff (2) $\theta = \frac{4\pi}{10}c\varphi\frac{l(b-a)}{D^2}$. Eliminating D in terms of m & r

$$D^2 = \pi l\,(b^2-a^2)\sqrt{\frac{\rho\sigma}{m r}} \quad \text{while } d^2 = \frac{4}{\pi}\sqrt{\frac{m\rho}{r\sigma}} \qquad (15)$$

whence $\theta = \frac{4\,c\varphi}{10(b+a)}\sqrt{\frac{m}{\rho\sigma}}$ and $= 0.0256\sqrt[4]{\frac{m}{r}}$ with $\rho = 1.7\times10^{-6}$

$0.0390\sqrt[4]{\frac{m}{r}}$ with $\rho = 1.8\times10^{-6}$

$$= \frac{4\varphi}{10(b+a)}\sqrt{\frac{m}{\rho\sigma}}\times\frac{E\sqrt{r}}{\beta+r}$$

$$\frac{d\theta}{dr} = J\left\{\frac{\frac{E}{2\sqrt{r}}(\beta+r)-E\sqrt{r}}{(\beta+r)^2}\right\}$$

for max $\beta + r = 2r$

or $r = \beta$

and $\theta = \frac{E\varphi}{5\sqrt{\beta}(b+a)}\sqrt{\frac{m}{\rho\sigma}}$

for copper $= \frac{E\varphi\sqrt{m}}{\sqrt{\beta}(b+a)}\times\frac{1}{2.0\times10^{2}}$

for D line $= \frac{E\sqrt{m}}{\sqrt{\beta}(b+a)}\times2.084$

$$= \frac{E}{\sqrt{\beta}}\sqrt{\frac{m}{a}}\times\frac{2.084}{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}$$

This is now nearly independent of the length.

To determine in this case the diameter needed, take (15)

$d^2 = 5.704\times10^{4}\sqrt{\frac{m}{\beta}}$

Conditions for securing the maximum indications from an optical galvanometer. contd. from page 99.

Let

c = the current in the helix (ampères).
e = " e.m.f. on " " (volts)
r = " resistance of " " (ohms)
R = " coiling space of " " (c.c.)
l = " length of " (cms)
a = " inner radius of " " (cms)
b = " outer " " (cms)
m = " mass of wire on " " (grammes)
n = " number of turns in " " per cms.
N = bn " " " " as a whole.
σ = " specific gravity of copper wire " " (8.95)
v = " difference of magnetic potential between ends of liquid column
θ = " rotation of the plane (in minutes of arc)
φ = " Verdet constant (minutes of arc) 0.01415' for D
d = " diameter of the wire (cms)
δ = " thickness of insulating covering (cms)
D = " diameter of covered wire (cms) $= d+2\delta$.
h = " energy dissipated in tube per sq. cm. surface (Watts).

Then

$$\theta = v\varphi = \frac{4\pi}{10}c\varphi N = \frac{4\pi}{10}\frac{e}{r}\varphi N \qquad (1)$$

$$N = \frac{l(b-a)}{D^2} \qquad (2)$$

$$r = \frac{4\rho l(b^2-a^2)}{D^2 d^2} \qquad (3)$$

$$\therefore\ \theta = \frac{\pi}{10}\frac{c\varphi d^2}{\rho(b+a)} \qquad (4)$$

but

$$b = a\sqrt{1+\frac{4mD^2}{\pi^2 l a^2\sigma d^2}}$$

$$= a\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}} \quad \text{where } q = \pi a^2 \sigma l \text{ the mass of the core in copper.} \qquad (5)$$

$$\text{and } d^2D^2 = \frac{8hb\pi l^2\rho(b^2-a^2)}{c^2} \qquad (6)$$

$$\therefore\ d^2 = \frac{\sqrt{l}}{c}\sqrt{\frac{32h\rho m a}{\pi\sigma}}\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}} \qquad (7)$$

$$\text{and}\quad \theta = \frac{\pi}{10}\frac{c\varphi l}{\rho\sqrt{a}}\frac{\sqrt{\frac{32}{\pi}\frac{hm\rho}{\sigma}}\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}{\left\{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}\right\}^{2}} \qquad (8)$$

$$\text{or}\quad \theta = \frac{4\pi}{10}\varphi\sqrt{\frac{lm}{a}}\cdot\sqrt{\frac{2h}{\pi\rho\sigma}}\cdot\frac{\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}{1+\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}} \qquad (9)$$

This expresses the rotation obtainable from a given weight of wire and shows that the sensitiveness of the apparatus varies as $\sqrt{\frac{l}{a}}$ nearly and also approximately as $\sqrt{m}$.

d can then be obtained from (7). in terms of c, l, a & m

If the instrument is needed for an ammeter of maximum current c, Then

$$d^2 = \frac{c}{\pi}\sqrt{\frac{8\,am\rho}{hq\sqrt{1+\frac{4m}{\pi q}\left(\frac{D}{d}\right)^{2}}}} \qquad (10).$$

$$\theta = \frac{4\pi}{10}\frac{c\varphi l(b-a)}{D^2}$$

Std = 0.009833 @ 23.5°C 23.5 − 20.8 = 2.7°C × 0.021 = 5.67 × 10⁻²,

1 × 10⁻² ×

= 0.009827 @ 20.8° C.

$9.827 \times 10^{-3} \times \frac{2712.5 + 1265}{2712.5} = 1.441 \times 10^{-2}$ ω.

$\frac{1.441 \times 2.8776 \times 10^{6}}{5.977 \times 10^{2}} = 6.9186 \times 10^{3} = 6919$

Resistivity of copper @ 20.8C. 1.753×10^{3}

Conductivity = 25.33 %.

$0.009827 \times \frac{4085 + 2712.5}{2712.5} = 0.03623$ ω.

$0.03623 \times \frac{2712.5}{2712.5 + 1950} = 0.02108$ ω

$0.02483 \times \frac{2712.5}{2712.5 + 1950} = 0.01427$ ω.

$6919 \times 10^{3} \times \frac{2742.5}{2712.5} = K \times \frac{1.753 \times 0.06022 \times 10}{4.79}$

$\frac{1.441 \times 10^{-2} \times 2742.5}{2712.5} = 1.457$

$\frac{1.457 \times 10^{-2} \times 6.022 \times 10^{-2}}{4.79} = 1832 = 95.5\%$

$\frac{1.44 \times 10^{-2}}{5.977 \times 10^{2}} = 2.409 \times 10^{-5} \times 1.6093 \times 10^{5} = 3.877$ ω per mile

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Tests of a sample of "Tobin" Bronze Trolley Wire

(117)

A 25 foot sample of this wire # 4 B.W.G. was received 10th Sept. 90. Its conductance was tested the same day.

Hart: & Brown galv: 15 ω in rt. hand oil adjusts balance. Quite differential in series. Res: of both 5.425 ω. − 2712.5 each. Stretched the bronze wire along floor, and soldered two fine copper wires near extremities. Compared with Std: 0.01 ω whose temp: was observed to be 20.8°C. With about 8 amp: current, deflections 250 d. ± Balance with 1265 ω added to wire.

2nd Test. Half of platinoid grid balanced against holly wire. Balance obtained with 1950 ω added to grid.

3rd Test. Half of platinoid grid balanced against 0.01 ω Std: 4085 ω added to grid.

4th Test. Stretched a length of # 12 wire along floor (diam 0.109"), and included it in main circuit. Attached pressure wires near its extremities. Balanced with 30 ω added to bronze wire.

Length of Bronze wire by steel tape between pressure wires: 598.0, 597.5, 597.8 } Mean 597.7 cms

Diameter - - - - micrometer: 0.2385", 0.2385", 0.2383", 0.2395", 0.2386", 0.2380", 0.2377"

Mean 0.2383" = 0.6053 cm.

Length of copper wire 479 cms. Sq. cms. 0.28776 sq. cms. 0.04464 sq. ins.

Diam 0.109" = 0.2769 [illegible] sq. cms.

Length	Diam.	Area.	Resistance @ 20.5°C	Resistivity @ 20.5°C	Conductivity in terms of pure copper @ 20.8°	Resistivity of pure copper @ Sydney	Resistivity of pure copper @ 20.8° C.
597.7	0.6053	0.2878	0.01444	6919	25.3 %	1624	1753

The tensile strength was observed by straining the wire from a piston fully working in a cylinder of oil. A pressure gauge on the cylinder and also an indicator (Old Tabor) were connected. The wire was bent over ——— and wrapped with copper binding-wire finally soldered in. The wire broke close up to the solder, as in our looking. The diameter of the cylinder was 10" that of the rod 1.375

Area of cylinder 78.54 area of rod 1.4844 difference 77.056

At the moment of fracture the gauge showed 40 lbs. } mean 42.5
indicator 45.

45 × 77.06 = 3468 lbs. ÷ 0.04464 = 77,750 lbs. per sq. ⊡.

For ductility a length of wire was clamped in the vice and the opposite end twisted up by a wrench. On fracture 12 twists were counted by the ink line in 12".

Two samples were weighed as follow.

No.	Length	Weight	Weight.	gms per m.	Mean	Area	Sp. g.	Weight per	
1	38.9	3oz. 160 grains	94.13 gr	2.42	2.43	0.28776	8.44	3 qr 21 lbs	86 a lb.
2	62	5 - 150 -	151.5 -	2.44					

Test of the Safety Conduit Tubes that are mentioned on page 105.

These tubes were left in the tank on the roof under water, from the 21st Aug. to the 12th Sept. — 22 days.

The following are results with three.

#1. Both ends corked and carefully sealed with paraffine wax. G.P. wire penetrating through one seal. Tube full of water and in trough of water (tap water).

Insulation by bridge 100/000 Z to L. 20,000 ω. 360 per mile
C . . 17,000 ω. 306 . .

#2. Same conditions as #1 Z to L. 15,000 ω. 27 . .
C . . 12,500 ω. 22·5
Mean 32·5

Seals were examined and received. Test then repeated with same results.

One tube was then removed from the trough, the seals sawn off, and the tube emptied. Some cotton waste soaked in brine was then introduced near the middle of the tube with a wire in it. The outer surface of the tube was next dried, and covered at the ends with a coating of paraffine wax. A jacket of waste soaked in brine was then laid on about the spot occupied by the waste inside, and the resistance from interior to exterior measured. The resistance was about 100,000 ω and the space covered about one foot long.

#3. Was sealed at one end. Being somewhat bent it was laid in trough with both ends projecting. It was covered with water only at its middle. Water was poured inside and a copper wire inserted for contact with this water. The exterior of the tube was dried. Res: between water in trough and water in tube about 70,000 ω.

Approx. Tubes dimensions Length 9' 6". Int: diam 1" Ext: diam 1⅞".

Measurement of Temperature supplied by Lalande Battery Solution before freezing, by Messrs Thompson & Glaisworth.
14th September 1880.

About 25 c.c. of solution of regular battery NaHO sp.g. 1·25 was cooled by freezing mixture. The lowest temperature reached was −16° C and there were no signs of freezing at that point.

Meteorological Records

Date		Barometer Readings Inches			Barometer Readings Inches at 0° Cent.	Thermometer Readings Max.	Min.	Dry	Wet	Rain &c. in 24 hrs.	Wind & Weather	Remarks.
Sept	13	29.493	75.42	74.0	29.527	80°	74°	80°	77°	1.02	S	Raining.
	14	29.907	75.48	67.0	29.806	71.0	62°	67.0	65.0	.9	N.W.	Fair.
	15	29.845	75.81	67.0	29.782	78°	60	70	67	.23	S.W.	Cloudy Overcast
	16	29.739	75.54	70°	29.625	73	66	68	68	1.15	S.W.	Heavy Overcast
	17	29.609	75.21	67°	29.509	71	64	65	64	.21	S.W.	Rain.
	18	29.391	75.66	67.0	29.621	71	56	66	64	.10	W.	Overcast
	19	29.815	75.87	68°	29.767	77	52	68	66		S	Fair
	20	29.845	75.71	70°	29.711	72	61	70	67		S.W.	Fair. Cloudy
	21	29.717	75.72	62°	29.722	72°	62°	63°	62°		S.W.	Overcast
	22	29.767	75.32	63°	29.768	72°	53°	66°	62°		S	Fair
	23											
	24	29.935	76.08	64°	29.850	70°	57°	57°	57°		N.W.	Fair.
	25	30.066	76.34	60°	29.982	69°	52°	57°	57°		S	Fair
	26	29.783	75.50	60°	29.447	64°	52°	62°	61°		S	Fair
	27	29.767	75.42	60°	29.635	70°	57°	67°	66°	.45	S.E.	Raining Overcast
	28											
	29	30.067	76.34	55°	29.988	63°	48°	57°	57°		N	Fair
	30	29.997	76.26	60°	29.913	66	41	57	57		N	Fair
Oct	1	30.025	76.23	60°	29.933	69°	50°	65°	60°		N	
	2	30.027	76.23	60°	29.923	70°	50°	65°	63°		N.E.	Cloudy
	3	29.763	75.66	60°	29.665	70°	62°	67°	67°	1.01	N.W.	Overcast Raining
	4	29.607	75.51	67°	29.502	70°	55°	67°	65°	.63	S.W.	Fair
	5	29.541	75.09	64°	29.537	71	57	67	65°		W	Fair
	6	29.725	75.07	64°	29.681	70	54	57	57	.05	N.W.	Raining Overcast
	7	29.579	75.13	61°	29.472	58°	50°	53°	53°	.43	N.	Raining Overcast
	8	29.817	75.81	60°	29.730	62	51	56	55	.13	W.	Fair
	9	30.019	76.25	60°	29.935	64°	40°	54°	52°		W.	Fair.
	10	29.897	75.79	63°	29.774	67°	43°	62°	61°		S	Overcast
	11	29.725	75.50	70°	29.585	66	55	60	57		W	Overcast
	12	29.493	75.12	60°	29.609	62	50	54	53			Overcast
	13	29.725	75.81	64°	29.669	55°	41°	51	50	.01	N.W.	Fair
	14	29.524	75.01	75°	29.400	57	52	55	55	.11	N.W.	Raining Overcast
	15	29.767	75.59	61°	29.660	57	43	57	56	.14	W	Fair
	16	29.865	75.84	77°	29.730	63	46	66	58		S	Overcast Fair
	17	29.517	74.59	67°	29.412	63	54	58	55	1.05	S.W.	Fair
	18	29.733	75.53	68°	29.637	63	46	55	53		S.W.	Fair
	19											
	20	29.503	74.94	76°	29.391	60	49	52		.05	N.W.	Overcast
	21	29.795	75.81	76°	29.663	55°	43°	51°		.03	N.W.	Fair
	22	29.765	76.03	72°	29.645	53	39	49			N	Fair
	23	29.949	76.05	73°	29.820	53	43	47			N	Fair Clouded
	24	29.387	74.65	72.0°	29.267	55°	41	54°		1.50	N.W.	Rain Clearing
	25	29.537	75.05	76°	29.405	50	43	48		.18	N.W.	Rain
	26											
	27	29.271	74.36	73	29.148	52	40	48			W	Fair
	28	29.495	74.47	78	29.357	51	40	40			S.W.	Fair
	29	29.173	74.11	77°	29.038	47	39	47		.07	S.W.	Rain
	30	29.471	74.91	73°	29.348	48	38	47		.105	S	Overcast
	31	29.733	75.33	65°	29.698	58	38	44			S	Fair
Nov	1	29.915	75.21	73°	29.672	47	35	46			S.W.	Fair
	2	29.503	74.55	60°	29.419	44	37	48			S	Fair
	3	29.587	74.16	76°	29.455	53°	40°	46°			S.W.	Fair
	4	29.633	73.32	76°	29.531	43	36	41			S.W.	Overcast
	5	30.031	76.28	76°	29.899	45	30	45			S	
	6	29.977	76.26	76°	29.895	50	35	50			S	Fair
	7	30.005	76.26	79°	29.864	55	43	53		.002	S.	Overcast.
Omitted	8											
	9											
	10	29.959	76.073	75°	29.550	65	40	61	50		NNW	Overcast
	11	30.058	76.163	74°	29.929	56	35	41	41	0.28	N	"
	12	30.048	76.343	74°	29.916	44	34	40°	42°	0.09	N	Fair
	13	29.913	76.013	70°	29.797	48	34	46	45		W	"
	14	29.911	76.003	62°	29.821	53	40	54	53		W	"
	15	29.943	76.083	71°	29.826	55	36	53	51		S.W.	"
	16											
Omitted	17	29.709	75.493	75°	29.580	53	40	51	51	0.24	S.S.W.	Rains & Overcast
	18	29.709	75.493	71°	29.595	62	51	52	50	0.06	NE	very fair
	19	29.554	75.052	78°	29.399	53	38	52	50		W	overcast
	20	29.845	75.153	70°	29.461	58	35	41	39		N.W.	fair
	21	29.919	75.023	72°	29.788	46	34	38	36		N.E.	Fair fair
	22	29.754	75.213	70								
	23	29.949	75.03	70								
	24	29.949	75.103	70	29.835	45	24	43	32		NW	Fair
	25	29.574	75.163	70	29.638	50	38	50	48		W	Hill
Omitted	26											
	27	29.919	75.773	75	29.690	53	35	29	27		N	Fair

Plan of Switch 1/20
30ft = 1"
Plank 4.8.1.
Radius 500
Radius 1000
Radius 2000
Radius 3000
Radius 4000

Traction Experiments at Schenectady.

15th Sept. 20

Experimental grade 6%. Distance of poles apart 50 feet.

Experimental truck operated by 2 Sprague motors with all the usual outfit and connections except the trolley.

Experimental trailer. a flat truck weighing 11000 lbs loaded with 10 cons of weight now each 9½" diam and 57" long) brake at each end. At 1000 lbs end total load = 11,000 lbs.

1st trial. 200 ft. up grade in 17 secs. = 12 ft per sec. = 8.2 miles per hr. operated at full power of motors (in parallel). Starting pull delivered to trailer 3000 lbs. Mean pull 900 lbs. = 20 HP at trailer.

2nd trial 200 ft up grade in 16 secs = 12.50 ft per sec = 8.52 miles per hr. operated at full power of motors. Starting pull 4500. Mean full on grade 600 lbs = 13.50 HP. at trailer.

3rd trial Started on commencement of grade. Running on 2nd mark of switch. 100 ft in 12 secs. = 8.34 ft per sec = 5.6 miles per hr. Starting pull 10,000 lbs. mean pull 800 lbs = 12 HP. at trailer.

4th trial Stopped on descent of grade. Dynamometer indicating 600 lbs

Theoretical amount 0.06 x 11,000 − 5.5 x 15 = 660 − 82.5 = 577.5 lbs.

taking 15 lbs tractive friction per ton.

5th trial. Started on grade (?) with brakes down. Starting pull 3200 lbs

Mean pull not known.

6th trial. Changed trailer for an empty coal freight car weight 21,000

Pulled same at full power up grade. Max. at start 8500 lbs.

Mean pull on grade 750? Time not observed.

16th Sept.

Pull of coal freight car 21,000 lbs. on level 8 miles per hr. = 500 lbs.

" " " " " " up grade 2000

2nd trial. Run up grade (Wheels slipping). Pull 1100 to 1500 lbs Time 100 feet in 29 secs. = 3.45 ft per sec = 2.38 miles per hr.

Starting pull 10,000 lbs.

3rd trial Full speed up grade 16 secs for 200 feet = 12.5 ft per sec. = 8.5 miles per hour. Mean pull 1200 lbs Max. 5500

4th trial Stopped on grade. Pull 990 lbs

Theoretical amount 21,000 x 0.06 − 5.5 x = 990

5.5 x = 1320 − 990 = 330

x = 60

5th trial Started up grade. pull 2000 lbs. reducing to 1500 Max 2200

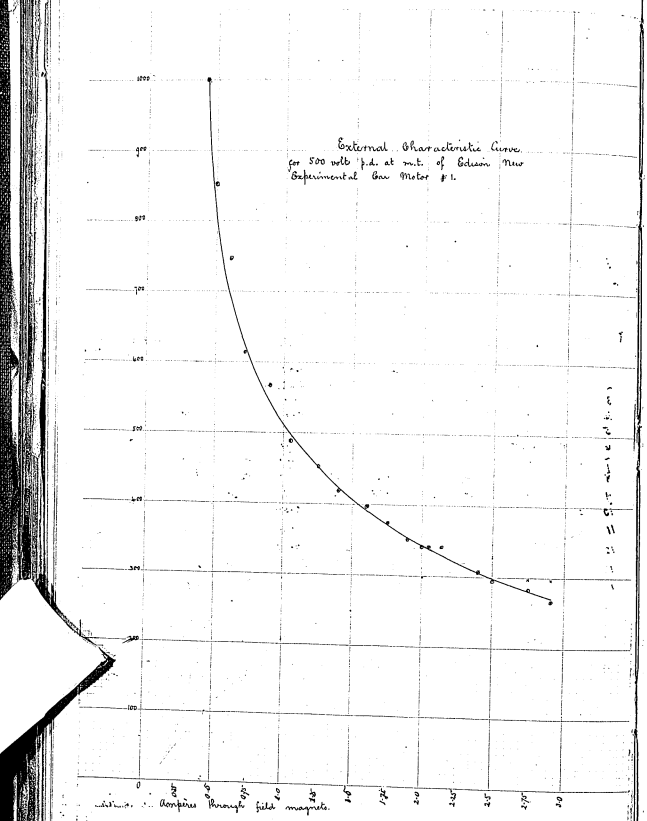
This run at full speed.

6th trial Came up grade on 2nd point of switch = 20 secs for 100'

1600 − 1300 lbs. pull. 5' per sec. 3.4 miles per hr.

7th trial Coming up on 2nd point of switch = 18 secs for 100'

1400 − 1200 lbs. pull.



Test of New Edison Experimental Car Motor #1.

Schenectady. 15th Sept. 1890

Resistance of armature between brushes
" field magnets 8 in series

A large ~~wooden~~ pulley was placed on one end of the shaft, and a belt taken to another dynamo, intended to absorb power. The fields of this dynamo was not excited so that the power absorbed by the motor had only to overcome the electrical and mechanical friction of its own armature and the mechanical friction of the armature.

The following observations for magnetic saturation were first made.

No. of Obs.	P.D. on Fields	Current in fields	P.D. on armature	current in armature	Speed Revs per min	Speed Reduced to 500 volts on mt.			
1	600	2.92	600	–	320	267			
2	550	2.75	550	–	310	282			
3	500	2.5	500	–	295	295			

The armature was next operated from the 220 volt circ: and the fields from the 500 volt machine with following results.

No. of Obs.	P.D. on fields	Current in field circ.	Energy in field circ. watts	P.D. on armature terminals	Current in armature circuit	Energy in armature watts	Energy per ampere per minute	Speed revs per min.	Speed revs per min. reduced to 500 volts	Fall of potential in armature	Direction of Rev. loc.
1	600	2.92	1750	220	1.8	396	2.27	130	296		
2	560	2.75	1540	"	1.8	396	2.27	120	296		
3	488	2.4	1170	"	1.8	396	2.99	135	307		Start.
4	435	2.14	932	"	1.8	396	2.64	150	341		
5	418	2.00	836	"	1.9	418	2.78	150	341		
6	425	2.05	871	"	1.9	418	2.78	150	341		
7	375	1.9	712	"	2.05	451	2.91	155	352		
8	355	1.75	621	"	2.05	451	2.73	165	375		
9	328	1.60	525	"	2.05	451	2.58	175	398		
10	285	1.4	399	"	2.1	462	2.50	185	420		
11	252	1.25	315	"	2.1	462	2.31	200	454		
12	215	1.05	226	"	2.3	506	2.35	215	488		
13	178	0.90	160	"	2.5	550	2.20	250	568		
14	148	0.77	114	"	3.3	704	2.61	270	613		Medium
15	125	0.62	77.8	"	4.0	880	2.67	330	749		
16	110	0.5	55	"	5.3	1166	3.11	375	851		
17	87	0.43	37.5	"	7.0	1540	3.50	440	1000		Fast.

18 530 2.4 1272 – Temp. on field (One hour's application field + armature 42°C. in 23° air 21°C.)

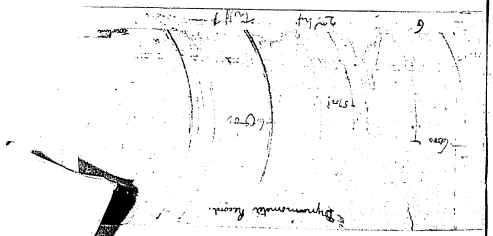
19 50 amperes (falling to 48) delivered to lamp bank through armature (with) continuously for half an hour. Fields not excited. Temp. on armature surface 72°C., Air 23°

Weight of complete motor (including girders 3 ft 6 ins. :- Armature & shaft 790
Fields complete 2480
Armature & pulley 497
3767

Test on 16th Sept. Motor running for one hour 530–600 volts p.d. about 49 amperes 26,000 to 29,400 Watts. Temp. on armature 76°C. Room 25°C. Fields at full pressure, Speed 295.

Checked dynamometer as follows –

A ~~cast~~ iron heifer 82·5 × 33·5 × 26·2 or 72,410 c.c. weighed by scales 1272 lbs
577 kgrs = 7.967 cwt. weighed on dynamometer indicated 1250.



Test of Magnetic Clutch Power – Preliminary.
at Schenectady 16th Sept. 90.

No. of Obs.	No. of Clutch	Current in clutch	P.D. on Clutch	Energy in Clutch	Weight employed	Dist. off centre feet	Torque	Pull at one weight pounds	
1	1	50	1.25	62.5	105 lbs.	4.5	473	280	
2		40				4.4	462	284	
3		30				3.5	368	295	
4		20.5				3.0	315	252	
5		9				1.5	157	1~~50~~	
6	2	50				3.5	368	293	
7		39				2.8	294	240	
8		30				2.5	262	208	
9		20				2.0	210	168	
10		10				1.4	147	120	

Traction Experiments at Schdy.
Synopsis of Results.
18th Sept. 90.

Trip	Obs.	Pole.	Time	Rate ft per sec	Switch	Amperes	Volts ※	Power Watts	Pull	Weight moved	Energy expd. mechly	Efficiency	Rate miles per hr.	Tractor Wt	Motor Gen Wt.
1	1	8	37	9.1	Full.	32	520	16,640	700					21,000 +3×200 +800 +100 29,250	3200 1100 700 5,000 18,400 29,600
	2	7	48	10		34	510	17,340	600						
	3	6	58	16.7		20	520	10,400	200						
	4	5	64	11.4		14	520	7280	0						
	5	4	71	11.3		30	510	15,300	80						
	6	3	80	11.1		83	480	39,840	1500						
	7	2	92	8.3		85	475	40,375	1400	39,650					
	8	1													
2	1	8	39	8.3	Full	30	520	15,600	Not	10,500			–		
	2	7	51	12.5		15	520	7800	observed						
	3	6	59	14.3		11	520	5720							
	4	5	66	14.3		50	520	26,000							
	5	4	73	14.3		34	520	17,680							
	6	3	80	14.3		38	520	19,760							
	7	2	87	14.3		29	520	20,300							
3	1	8	.0	5.5	Full	28			500	39,650					
	2	7	19	11.1		35			700						
	3	6	29	7.1		25			250						
	4	5	44	14.0		14			0						
	5	4	69	2.5		31			1200						
	6	3	108	7.7		82			1500						
	7	2	121	9.1		86			1700						
	8	1	132			0			0						
4	1	7	40	14.3	Full	30	520	15,600	Not	10,500					
	2	6	47	20		27	520	14,040	observed						
	3	5	52	25		20	520	10,400							
	4	4	56	12.5		25	520	13,000							
	5	3	64	12.5	rev.	34	520	17,680							
	6	2	72	14.3		38	520	19,760							
	7	1	79			0	520	-							
5	1	4	–	–	stopped	–	–	–	1550 lb	pull of	brake				
	2				Shorted	86 to 100	475	47,500	1900						
	3				-	60	490	29,400	–	with not	heater				
	4					50									
	5					40									
	6					35									

※ These numbers are 20 in error.

wire	armature	wire	
0·043	0·043	0·043	48 sections wire brush on 2
0·043		0·043	

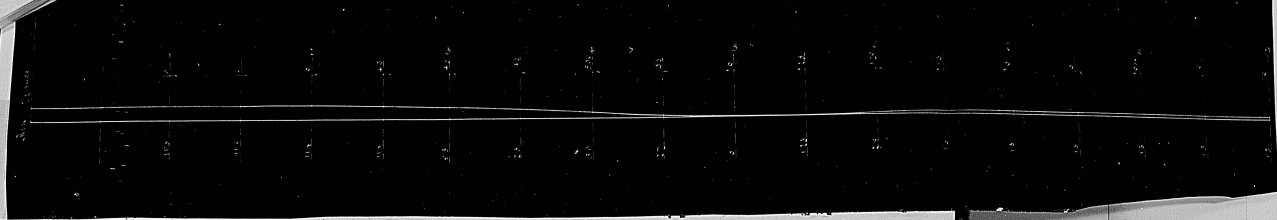
wire	armature	wire	
0·056	0·043	0·056	48 sections wire brush on 2
0·056		0·056	

brass	armature	wire	
0·186	0·043	0·056	24 sections wire brush on 1 or on 2

Experimental Car Inch.

?

Sayreschby Works. Sept 20th 1900.



Sparking Experiments.

Sept. 20.

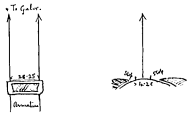
Comparison between two # 4 armatures successively placed in the same field. Armature #1 was of the ordinary standard type. With the fields at 125 volts and no load, the brushes could be shifted 3/16", without excessive sparking from the neutral line, or mid (blocks. With the full load of 80 amperes on the machine (dynamo 1620 rev.) the neutral line shifted 3/16" of an inch or the permissible previous limit, and could be moved again from this point 3/16" of an inch on either side without excessive sparking. Brush reading on 2½ bars. Exceeding these limits very heavy sparking resulted.

Armature #2 had g.s. connecting wires to the commutator. The res. of each wire was 0.0425 or 12 × res. of one coil = 1 × res. of armature with brush on 2 bars. When field excited and no load, there was very little sparking all round the commutator. The brushes could be set at the centre of e.m.f. without any (very) heavy sparking. On connecting up to a circuit and running as a dynamo the neutral line shifted on full load 3/16" and any position of the brushes could be tolerated. 125 volts.

When run as a motor, the sparking was much heavier, there with fields 70 volts + 50 amperes load. Driving engine running as motor, an excursion of only 2" could be tolerated. The limit reached was not so much the sparking as the heating of the g.s. wires. With fields 125 volts + 20 amperes motor load there was also heating of the wires.

The german silver wires were next cut, so as to double their resistance and halve their area. This produced a still greater immunity from sparking. The excursion tolerated from the neutral point was 2½". with 20 volts on the fields + 80 amperes.

The (single) german silver wires were then halved in number, and the bars doubled connected in pairs. This made the sparking much worse. The range permissable with no load running as a motor on 125 volts was 1⅞". On applying full load at 125 volts the range was only 1" and there was some point of complete sparklessness. This condition was not much exaggerated however when the p.d. was reduced to 20 volts.



Res. of Galv 6,200 ω.

$$118{\cdot}65\ H = d \times 1{\cdot}8411 \times 10^{-10} \times 6{\cdot}2 \times 10^{12}$$

$$H = 10\ d.$$

If v be the peripheral velocity $= \pi d n v$

$d = 60{\cdot}8 \quad \pi d = 190{\cdot}9$

and b be the mean breadth of wire

Then the emf. in the section under the brush is

$$2n\ b\ H \times 190{\cdot}9\ v = 2n \times 20 \times 190{\cdot}9\ v H$$

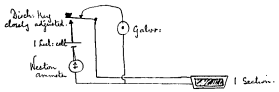
$$e = 1{\cdot}375 \times 10^5\ v H$$

If $H = 400 \qquad = 5{\cdot}5 \times 10^7\ v$

Standard Daniell solution

$CuSO_4$ 1·26

$ZnSO_4$ 1·16



Motor Determinations at Schenectady

September 22nd

(124)

Connected a wire vertical rectangle over the motor armature so as to be movable parallel to itself along the armature periphery. By limiting the motion to three sections, accelerating its motion with elastic bands, and connecting up to a Thomson galvanometer the normal component of the armature field was determined.

	Capacity of bands.	Estimated value of Sec. ult. Deull	Throw	a	a per div:				
	$\frac{1}{3}$ ℓ	1·05	±190 div.	$3{\cdot}5 \times 10^{-7}$	$1{\cdot}8411 \times 10^{-10}$				
Obs.	Current in field. amps.	Current in armature amps.	Observed throw.	Mean	Mean normal component	Dimension wire.	emf. at 2·20 ωm. volts	emf. at 4·60 ωm volts	emf. @ 700 ωm. volts.
1	2·5	0	−1	−1					
2	"	48	42 35 37 37	38	380	28·25 cm length + 4·2 cm of throw. = 118·65 sq. cm.	2·05.	4·10	6·25
3	0·7	50	43 38 38 36	39	390				
4	0	50	32 35 32 37	34	340				

To determine the inductance of the sections, one of them was disconnected, and brought out. Wire from its terminals were connected up with the galvanometer and discharge key as shown.

With a current of 0·173 amp: the discharge was 15 divs:

Let e be the emf. in a circuit

r . its res:

l . its inductance

c - its flow

Then on removing e, the equation of motion is

$$l\frac{dc}{dt} + cr = 0$$

$$\frac{dc}{dt} + \frac{c}{T} = 0 \qquad \text{if } \frac{l}{r} = T$$

$$\therefore c = \kappa\, \varepsilon^{-\int \frac{dt}{T}}$$

$$= \kappa\, \varepsilon^{-\frac{t}{T}}$$

when $t = 0$ $c = C$ $\therefore \kappa = C$

$$c = C\varepsilon^{-\frac{t}{T}}$$

$$dq = C\varepsilon^{-\frac{t}{T}}\,dt$$

$$q = C\int_0^\infty \varepsilon^{-\frac{t}{T}}\,dt$$

$$= CT = \frac{Cl}{r} \qquad \therefore l = \frac{rq}{C}$$

$$q = C\int_0^\infty \varepsilon^{-\frac{t}{T}}\,dt = -CT\varepsilon^{-\frac{t}{T}} = -CT\left(\varepsilon^{-\frac{\infty}{T}} - 1\right)$$

In this case $r = 6{\cdot}2 \times 10^{12}$ $\quad q = 15 \times 1{\cdot}8411 \times 10^{-10}$ $\quad c = 1{\cdot}73 \times 10^{-2}$

$$\therefore l = \frac{6{\cdot}2 \times 1{\cdot}5 \times 1{\cdot}8411}{1{\cdot}73} \times 10^5 = 9{\cdot}9 \times 10^5 = 9{\cdot}9 \text{ kilometres.}$$

For this particular motor, the armature res. being 1·33, equivalent to $\frac{32}{4}$ blocks $= 0.166\ \omega = 1.66 \times 10^{5}$

$$L = 9.9 \times 10^{5}$$

$$T = \frac{9.9 \times 10^{5}}{1.66 \times 10^{8}} = 6 \times 10^{-3} = 0.006 \text{ seconds.}$$

$$\theta = \frac{2}{128\,n} = \frac{1}{n \cdot 64} = \frac{1}{18.66 \times 64} \quad \text{for } n = 18.66$$

$$= \frac{1}{746}$$

$$= 0.001134.$$

$$\frac{\theta}{T} = \frac{0.001134}{0.006} = 0.223$$

$$\varepsilon^{\frac{\theta}{T}} = 1.26$$

$$\frac{1}{\varepsilon^{\frac{\theta}{T}}} = 0.794$$

$$1 + \varepsilon^{-\frac{\theta}{T}} = 1.794$$

$$1 - \varepsilon^{-\frac{\theta}{T}} = .206$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = 8.7$$

$$C = 1.25$$

$$\sigma = 8.7 \times 1.25 = 10.9 = 109 \text{ amp.}$$

$$e = 18 \text{ volts active in opposite direction } 6$$

At slow speed. $\frac{\theta}{T} = 0.67$

$$\varepsilon^{\frac{\theta}{T}} = 2$$

$$\varepsilon^{-\frac{\theta}{T}} = 0.5$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = 3$$

$$C = 1.25$$

$$\sigma = 3.75 = 37.5 \text{ amp}$$

$e = 6.3$ volts. volts active in opposite direction 2.

Assuming 4 times as many sections in the armature, $T = 0.04415 \times 10^{-3}$

$$= 4.15 \times 10^{7}$$

$$\frac{L}{T} = \frac{9.9 \times 10^{5}}{16 \times 4.15 \times 10^{7}} = 0.00149$$

$$\theta = 0.00113$$

$$\frac{\theta}{T} = 0.9$$

$$\varepsilon^{\frac{\theta}{T}} = \varepsilon^{0.9} = 10^{0.391} = 2.47$$

$$\varepsilon^{-\frac{\theta}{T}} = 0.405$$

$$\frac{1+\varepsilon^{-\frac{\theta}{T}}}{1-\varepsilon^{-\frac{\theta}{T}}} = \frac{1.405}{0.595} = 2.36$$

$$C = 1.25$$

$$\sigma = 2.36 \times 1.25 = 2.95 = 29.5 \text{ amp.}$$

$$e = 1.2$$

Determination of the equations of motion in a dynamo or motor segment under a brush.

(125)

Let n be the number of revs: per second.

- H - - normal mean field at the neutral point.
- $\mathfrak{B}$ - - number of sections in the armature.
- ϖ - - - - wires in the section.
- c - - current in the section at any time abs.
- $\mathcal{C}$ - - - in the armature sections abs.
- r - - res: of the section abs.
- ρ - - external res: to the section abs.
- L - - inductance of the section emu.
- b - - mean breadth of armature wires.
- e - - e.m.f. generated in it by closing cct.
- D - - diameter of the armature.
- h - length of brush surface, j be length of bar + mica thickness

Then $e - L\frac{dc}{dt} - c(r+\rho) = 0$

$$\frac{dc}{dt} + \frac{c}{T} = \frac{e}{L} \qquad \text{where } T = \frac{L}{r+\rho}$$

$$c = \varepsilon^{-\int \frac{dt}{T}}\left(\int \varepsilon^{\int \frac{dt}{T}} \frac{e}{L}\, dt + K\right)$$

$$= \varepsilon^{-\frac{t}{T}}\left(\frac{e}{L}\int \varepsilon^{\frac{t}{T}} dt + K\right)$$

$$= \varepsilon^{-\frac{t}{T}}\left(\frac{e}{L} T\, \varepsilon^{\frac{t}{T}} + K\right)$$

$$= \frac{e}{r+\rho} + K\, \varepsilon^{-\frac{t}{T}}$$

when $t = 0$ $\quad c = \mathcal{C}$

$$\mathcal{C} = \frac{e}{r+\rho} + K \qquad \therefore K = \mathcal{C} - \frac{e}{r+\rho} = \mathcal{C} - \sigma$$

when $t = \infty$ $\quad c = \frac{e}{r+\rho} = \sigma$

$$c = (\mathcal{C} - \sigma)\,\varepsilon^{-\frac{t}{T}} + \sigma$$

$$= \mathcal{C}\,\varepsilon^{-\frac{t}{T}} + \sigma\left(1 - \varepsilon^{-\frac{t}{T}}\right)$$

$$e = \varpi\, 4 H \pi n D$$

$$t = \frac{2}{\pi n} \text{ approximately for a 2 bar brush or } \frac{h - (j - m)}{\pi n} \text{ accurately}$$

To completely overcome sparking we must have at time $\frac{2}{\pi n}$ or θ

$$-\mathcal{C} = \mathcal{C}\,\varepsilon^{-\frac{\theta}{T}} + \sigma\left(1 - \varepsilon^{-\frac{\theta}{T}}\right)$$

$$\sigma = \frac{\mathcal{C}\left(1 + \varepsilon^{-\frac{\theta}{T}}\right)}{1 - \varepsilon^{-\frac{\theta}{T}}}$$

Standard Sprague Motors

Style 17	Total Weight of wire on Magnets	Weight of wire on armature	Total cost of wire.		Lbs wt per H.P.	Lbs wt. complete Total weight
1/2	15 lb	2.9 lb	13	00	260	348
1	22 "	4.5 "	14	62	202	271
2	32 "	9.6 "	21	85	164.5	221
3	50 "	13.6 "	29	35	146.7	196.7
5	76 "	21 "	38	00	137.8	184.7
10	100 "	18.3 "	44	50	100.5	134.7
15	166 "	36 "	74	05	96.8	129.8
20	226 "	68.5 "	104	81	96.2	122.3
25	340 "	86.5 "	147	50	137	183.7
35	410 "	102 "	183	10		
50	578 "	169 "	265	75		
75	800 "	252 "	371	00	156	209.1

C. F. Hy.

1.05 watt × 0.33 f = 0.35 × 10^-7 Q gauss 178 dim.

1 dim = 1.67 × 10^-10 V

$l = \frac{Vy}{2} = \frac{6.3 \times 10^{-10} \quad q = 3.0 \times 10^{7} \times 1.67 \times 10^{-10}}{2.7 \times 10^{-3}}$

$= \frac{1.86 \times 1.067}{2.7} \times 10^{4}$

$= 1.355 \times 10^{4}$

$= 13.55$ kilomilles.

$q = 9.5.3 \times 1.067 \times 10^{-10} = 1.01.5 \times 10^{-10} = 1.075 \times 10^{-8}$

$f = 106.200 \times 10^{3} = 1.062 \times 10^{10}$

$f = 1.075 \times 1.062 \times 10^{6} = 1.991 \times 10^{6}$

Time of one revolution is 3.182 × 10^6 sec. for 5700 revs @ 2.25 mph

$q_{\text{mag}} = 4.96 \times 10^{6}$

$f = \frac{4.96 \times 10^{10}}{5.333 \times 3.075 \times 10^{6}}$

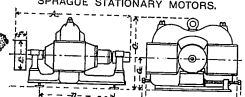
$= 3.025 \times 10^{6}$

$v = \frac{3.1.82}{3.025} = 1.315$ ~ Lenz = 23.67 ft/sec

$\phi = 9.260$ sec. the same @ 2.25

No. B. W. Gauge.	Diameter in Mils.	Circular Mils d 2.	Pounds per 1000 ft.	Feet per Pound.	Ohms per 1000 ft.	Feet per Ohm.
4/0	454.	206116.	623.84	1.6030	.050368	19854.
3/0	425.	180625.	546.75	1.8290	.057471	17400.
2/0	380.	144400.	437.08	2.2879	.071891	13916.
0	340.	115600.	349.90	2.8579	.089802	11136.
1	300.	90000.	272.41	3.6709	.11535	8669.6
2	284.	80656.	244.13	4.0962	.12871	7769.5
3	259.	67081.	203.04	4.9251	.15476	6461.8
4	238.	56644.	171.46	5.8325	.18327	5456.5
5	220.	48400.	146.50	6.8259	.21448	4662.4
6	203.	41200.	124.73	8.0171	.25191	3969.7
7	180.	32400.	98.070	10.197	.32040	3121.1
8	165.	27225.	82.405	12.135	.38131	2622.6
9	148.	21904.	66.299	15.083	.47394	2110.0
10	134.	17956.	54.349	18.400	.57815	1729.7
11	120.	14400.	43.586	22.944	.72092	1387.1
12	109.	11881.	35.961	27.808	.87378	1144.5
13	95.	9025.	27.318	36.605	1.1502	869.41
14	83.	6889.	20.853	47.965	1.5068	663.64

DIMENSIONS, WEIGHTS AND OTHER DETAILS OF SPRAGUE STATIONARY MOTORS.



H. P.	A.	B.	B_2.	C.	D.	E.	F.	G.	Speed.	Weight in Lbs. Net.	Shipping.
¼	14⅛		11⅛	7⅞		2½	1⅜	3½	2000	54	66
½	20	17⅞	13⅞	12¾	11⅞	2⅝	2	6¼	1900	130	230
1	22⅝	17⅞	16¾	14⅝	13¼	4⅛	2½	7¼	1800	202	322
2	26¾	19	20	16⅝	15⅞	5	3	7½	1650	320	479
3	31⅛	19⅞	22½	18⅛	19½	6	3½	8⅞	1650	440	600
5	34	21¼	25⅝	22¼	20¾	8	4	11	1400	689	915
7½	37	21⅝	27½	24⅛	22⅝	8½	5	11½	1300	854	1097
10	39	22¼	30⅝	24⅝	25	9	6	12½	1200	1005	1329
15	45½	22½	33⅝	28¼	28½	10	7	12⅞	1200	1452	1961
20	49¾	24	36⅝	29⅝	29¾	11	8	14	1100	1824	2256
25	56½	25	41½	32¾	33¾	12	10½	15¾	850	3419	3792
35											
50											
75	80¼	46	62	54⅛	51⅝	24	12	26½	500	11863	13652

The speed of the ¼ H. P. motor, as given, is with full load.
Speeds of all machines vary somewhat from table. On this account, driven pulley should not be put on shaft until motor card, giving exact speed of machine, has been received.

Measurements of the inductance and induction in the car motor.

Schenectady 23rd Sept. 20.

Repeated measurement of inductance of one section. An attempt was made to determine how this varied with the variation of current in the field or armature. But owing to the unsteadiness of this current, this failed. Recourse had therefore to be made to the simple inductance of the section unmagnetised.

Mean current ·0.27 amp. Mean throw on release of key 30 divs. 1.05 volts × 0.33 ~~f~~ = 17⅞ divs. Mean inductance

Wrapped one turn of wire round a single core, near the brass plate. This turn was led to the galvanometer through 100000. With 2.25 amps. in field, made throttle but not reversed the mean throw was 95.3. divs. the mean induction

Schenectady

Trial of the Clutch after enlargement and reboring

Current 43 amperes 370 lbs (8½" × 6½" × 22¾" keyway ⌀6) supported at a radius of 42½". This is a moment of 15,730 inch-pounds at 1" or 1050 lbs applied to the periphery of the 30" car wheel. The two clutches should therefore give 2100 lbs at the available pull with 43 amperes.

Orange 24th. IX. 90

Trial of the Carrying Capacity of platinoid wire.

Two wires were tried, of platinoid, one 0.032" the other 0.013" diam. 21 B&S. These were tested for their carrying capacity, supported horizontally in air. The larger carried 6 amperes at a temperature say 20°C, and the smaller 2.5 amperes. By our tables this is quite to be expected.

Particulars concerning different types of small Motors.

Name	Power	Weight	Wt. per hort	Speed Revs. per min	Speed × Wt per hort.	Wire on armature	Wire on field.		
Sprague		202		1800		4.9	21		
Edison	1000	270	270	2100		3.9	28		
"	5000	830	166	1800		20.1	51		
G.W.	1000	162	144	1060		6½	9¾		
	5000	475	95	900		16	20		
Sedg. Quad	2500	–	–	1600		4	50		

Calculation of the Diameter of German silver wire necessary to safely connect the armature and commutator in the Experimental Car Motor # 1.

Basis assume the brush to always rest upon two and only two bars, that full load is 50 amperes, that four brushes are used, and that the convection is ~~[illegible]~~ for still air with 80° rise:

There are 512 sections wire with 4 brushes, 12 active at any one moment or each is active 1/43 rd of the time.

Let d = the diameter of the wire (cms)

" r = " resistivity " " (ohms) at working temp.

Its res: per cm: is $\frac{4r}{\pi d^2}$

The energy developed by a current of c amperes per cm: in one second =

$$\frac{1}{43} \times \frac{4c^2r}{\pi d^2}$$

The radiation per cm = $0.0577\,\pi d$ Watts

" convection " " = 0.00175×80 = 0.14 Watt.

$$\therefore \frac{4c^2r}{43\,\pi d^2} = 0.0577\,\pi d + 0.14$$

$$\frac{4c^2r}{135.1\,d^2} = 0.0577\,\pi d + 0.14$$

$$4c^2r = 7.795\,\pi d^3 + 18.91\,d^2$$

$$= 24.5\,d^3 + 18.9\,d^2$$

Approximately $d^2 = 0.2116\,c^2r$

$$r = 21 \times 10^{-6}$$

$$= 4.444 \times 10^{-6}\,c^2$$

$$d = 2.108 \times 10^{-3}\,c.$$

$$c = 12.5$$

$$d = 26.3 \times 10^{-3} = 0.0263 \text{ cm} = 0.011''$$

$$c = 474\,d.$$

If d = 0.016" wire. = 0.041 cm.

c = 19.4 amp. 256 mils. = 13 mils per amp.

If d = 0.020" = 0.051 cm.

c = 23.7 amp

The res: per cm. of this 0.020" (0.051 cm) wire # 25 B&S. $= \frac{84 \times 10^{-6}}{\pi\, 2.5 \times 10^{-3}}$

$$= \frac{84 \times 10^{-6}}{7.85 \times 10^{-3}} = 10.7 \times 10^{-3} = 0.0107$$

res: of 8 cm = 0.086 ω.

The res: of two such wire = 0.172 + res: of two sections 0.25 ω.

The e.m.f. in the cct = 3 volts.

the current = 12 amperes.

On the Constants (necessary) for constructing the model Milwaukee Car track. (Mr. Geyers to Prack).

(Ohms for minimum see p. 147)

The res. of a circular mil foot = 10·5 ω. say.

- - - - -	mile	= 55·440	= 5.5440×10^{-6}
- - - 390,600 × 2	- -	= 7.094×10^{-8}	= ∴ 0·0071 ω per mile
- - - 250,000 × 2	- -	= 8.09×10^{-8}	= ∴ 0·0111 ω - -
- - - 180,625 × 2		= 1.535×10^{-8}	= ∴ 0·0152 ω - -
- - - 144,000 × 2		= 1.925×10^{-8}	= ∴ 0·0193 ω - -
- - - 115,000 × 2		= 2.410×10^{-8}	= ∴ 0·0241 ω - -
- - - 56,000 × 2		= 4.94×10^{-8}	= ∴ 0·0495 ω - -

The mean effective resistance of a car absorbing 20 ampères at 562 volts = 29 ω.

The scale of the map is 500' to 1" = 1 mile to 10·56".

With 1/10th loss of the resistance, the model should operate on 6·25 volts. The res. of the 390,600 × 2 wire should be 1·1365 × 0·0071 = 0·00807 ω per ft.

- - - -	250,000 × 2	- -	× 0·0111 = 0·01262 - -
- - - -	180,625 × 2	- -	× 0·0152 = 0·01750 - -
- - - -	144,000 × 2	- -	× 0·0193 = 0·02194 - -
- - - -	115,000 × 2	- -	× 0·0241 = 0·0274 ω - -
- - - -	56,000 × 2	- -	× 0·0495 = 0·0563 ω - -

each car will be 0·28 ω in 9·3 wire.

For practical sizes, the best wire of bare copper of

model 0·00807 ω	for the 390,600 × 2 wire would be	# 19 B&S	0·00801	or # 20 B&W.	0·00843
- 0·01262 - -	250,000 × 2	- -	# 21 B&S	0·01126	# 22 B&W. 0·01317
- 0·01750 - -	180,625 × 2	- -	# 23 B&S	0·0165 ω -	
- 0·02194 ω - -	144,000 × 2	- -	# 24 B&W.	0·0202	
- 0·0274 ω - -	115,000 × 2	- -	# 26 B&S	0·02555	# 25 B&W. 0·02581
- 0·0563 ω - -	56,000 × 2	- -	# 28 B&W.	0·05266	# 27 B&S 0·05223

Data concerning an Eickemeyer Model Gramme Ring Armature examined

26th Sept. 20.

This armature (in wood) has a diameter of 12·25" (31·11 cms) over wire, and 12" (30·5) over brass. Its breadth is 3" across base 3¼" over wire and 4¼" over pegs. It is wound in 132 sections of 4 wire each or 528 wires all round. Each wire is wound in two loops over the surface of the armature being held in place by pegs projecting from the sides, 40 wires lie between the sides of the loop, so that the sides are actually 42 wires apart.

If b be the breadth of an armature, then it only pays to employ Eickemeyer winding when $(2 + \sin\frac{\theta}{2}) \times 1.5$ is $< 2b$.

that is when $\sin\frac{\theta}{2} = \frac{2}{3}\frac{b}{r}$

The ratio of $\frac{b}{r}$ in our dynamos is never greater than $\frac{1}{3}$

$$\therefore \sin\frac{\theta}{2} = \frac{4}{9} = 0.4444 = \sin 26^\circ 22'$$

$$\theta = 55^\circ$$

or 6 poles.

The winding can only be advantageous at best with centripolar and probably only with rotipolar machine.

In the Edison carbon #1 $\frac{b}{r}$ is 1·75, so it would be advantageous in this case.

On the Trial of a Sample Recording Ammeter Constructed by Messrs White & Pillington.

26th Sept: 20.

A double-conical barrel 8 cm long revolves by clockwork on a horizontal axis, in the plane of an ordinary solenoid ammeter fixed vertically above it. It bears 20 fibre plates radially projecting from its surface. These plates are cut away on one side of a line that passes spirally in one turn round the barrel. The barrel in this instrument revolves once in 6 mins.

Attached to the moving indicator arm, and partaking of its motion is a second arm pivoted on an horizontal axis at right angles to the direction of motion. The lower end of this arm is provided with a blunt stud that engages in the teeth of the barrel. The upper end carries a pawl engaging in a toothed wheel. When the stud engages with a plate it compels the toothed wheel to advance two teeth before release. The position of the ammeter arm therefore determines the number of plates that shall engage the recording arm per revolution, and hence the number of steps indicated by the train of wheel attached to the toothed wheel. In this particular model, the ammeter indicates up to 10 ampères (20 lamps) and there are 60 teeth in the escapement, and one revolution of this wheel indicates 10 on the dial, the full indication of 10 ampères then registers $\frac{10 \times 60}{60}$ in one revolution of the barrel or 6.7 or 6.67 per hour so that one amp. hr. indicated represents 6.67 on the dial, one lamp hr (one plate engaging per revolution) 3.33 per hour.

The instrument over indicated at first 9.2 amp for 7.8 about two hours later it fell to 8 ampères, (indicated).

The test commenced at 13.~~25~~ with a Standard Meter in cct. The ~~second~~ test was stopped at 9.15 on the following morning the current having been 13½ hours, and the mean indication 8 ampères = 106 amp. hr. or 700 on the dial.

The actual record was 027505 − 026830 = 675

Between 14.45 and 17.15 = 2½ hrs @ 9.0 amp = ~~22.50~~ amp. hr = 150.0 on the dial the record was 027.041 − 026.900 = 141.

An alternating current of approximately 7 ampères mean strength gave an indication of about 5 on the meter.

The res: of the instrument is 0.03 = giving a drop of 0.3 volts on full load. It has an inductance of $\frac{10.000 \times 0.1 \times 0.1}{100,000}$ = 1 kilometer, and the solenoid is composed of 66 turns in a quadrant of 1¼ layers.

The meter record was as follows.

Standard meter #1	47.863	48.0446	+ 0.183 } 0.186
	47.925	47.736	− 0.189

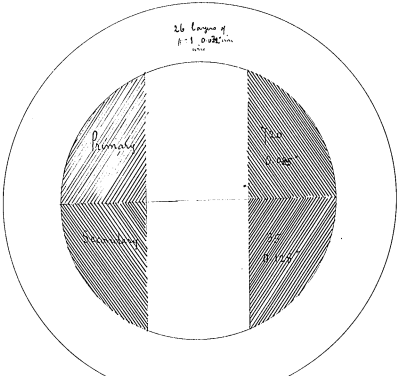
0.186 × 1000 ÷ 0.224 = 15.2 amp. hr @ 13½ = 11.47 amps.

Facts Concerning the relation between Illumination and Power in a 100 volt 16 c.p. lamp.

a 100 volt 16 m.c.p. lamp operating at 3.06 w. per c.p. takes 0.49973 amp. w. 2.0108
the same lamp at 101.02 volts takes for 17 c.p. 0.5038 " " " 2.005

The ratio of illumination is $\frac{17}{16}$ = 1.0625 the ratio of current is 1.01307

$(1.01307)^5$ = 1.0671 so that the illumination varies nearly as the fifth power of the current.



Comparison of magnetic circuits in an Edison & a Westinghouse transformer

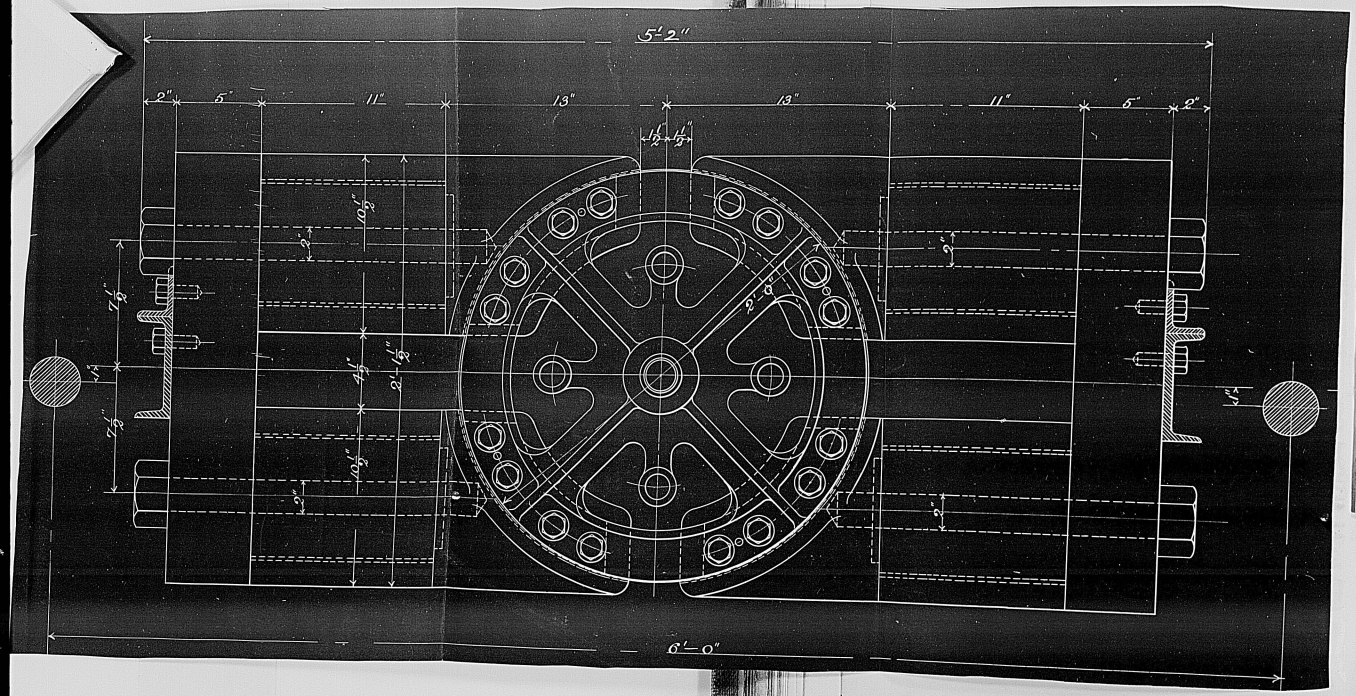
The Westinghouse transformer is already described on page 10. Edison transformer is on the same lines as that described on page 109, but with modifications in the arrangement of iron as follows:— Breadth of internal band 3·75
ext: diam. 14·3
int: " 9·95
length 20·7

720 turns on the primary in 2 lbs. 12 oz. of # 22. B+S. 0·025".
35 turns on the secondary in 3 lbs. 7 oz. of #8. B.+S. 0·128".
Total weight of 4 lbs 4 oz or 35 lbs of iron wire

With the two primaries in multiple, and the Siemens dynamo running at 107 periods per sec. 1600 revs. per min: the W. gave 44. on dynamometer with ann. antiinductive circuit while the E. gave 38, a ratio of 1·07 at 1680 revs. per min: or 112 ~ the W. gave 48, the E 39. a ratio of 1·11 so that the Edison transformer is in defect 10%.

E.M.F.	Opt. $\int_1^{(t)}$	Throw	Opt. per div.	
2 B. Cells 18°C	$2{\cdot}869 \times 10^{-7}$	139·5	$2{\cdot}057 \times 10^{-9}$	

No. of No.	Annulus	Amplitude in spring	Throws	Mean	Opt. in cent	$\frac{\Omega}{\Omega_0}$	$\frac{\phi}{\phi_0}$	Total R. in cent.			
Ext. 1	9°30'		·4	158	0	$3{\cdot}147 \times 10^{-7}$	2·368	5250			
2	16°45'		4	72	25,000	1·48		30,250			
3	52°		3	161	50,000	3·31		55,250			
4	0·200		3	84	102,000	1·73		105,250			
5	0·40		2	142	"	2·92					
6	0·79		3	213	"	4·38					
W. 1	0·80		3	198	-	$4{\cdot}07 \times 10^{-7}$		105,250			
2	0·435		3	178	-	3·66					
3	0·21		3	160	-	3·29					
4	55°5'		3	160	.	3·29					
5	160°		4	155	50,000	3·19		55,250			

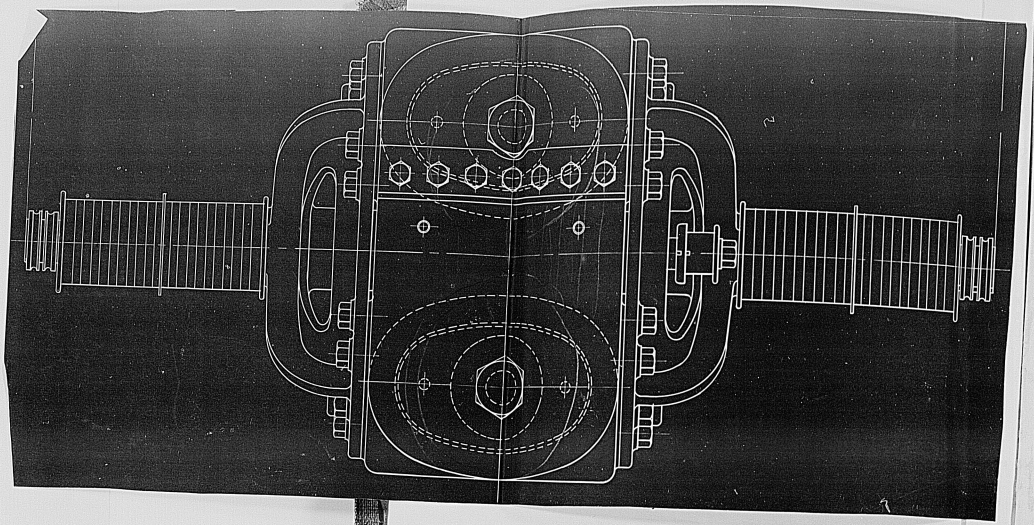


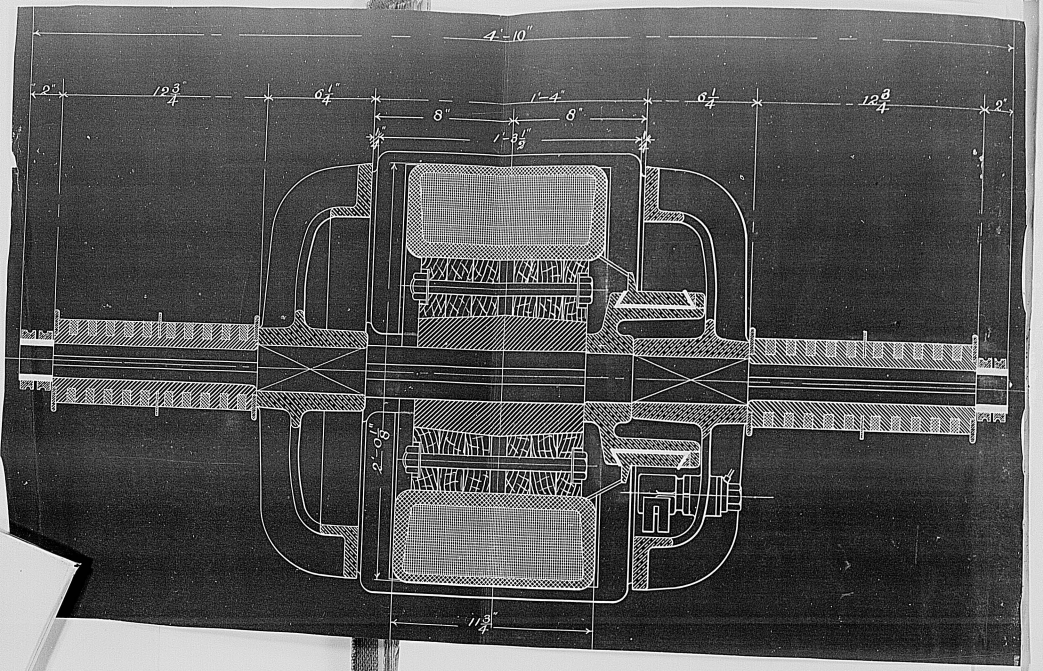
No. 2

Edison Street Car Motor

Scale 3" = one foot

Oct 7th 1890



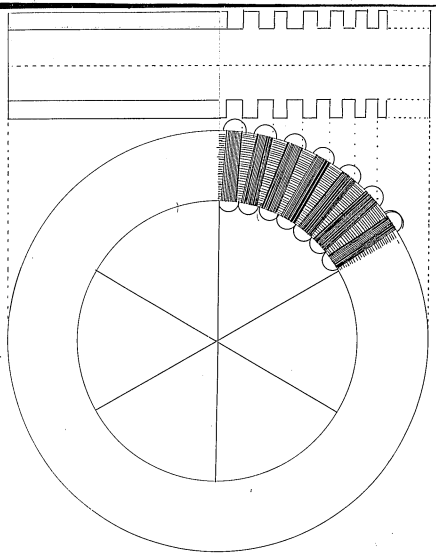


Modifications in
arrangement of

The cross section of one
By arranging the magne
it will be necessary to
This would in a
room for this, an
sufficient, so that the
outwards. Allowing
would be 10 1/2" x 10 1/2"
the core length 11" (27
sq. cms. Allowing 2 am
per Watt. It is therefo
2 amperes @ 500 volts
will be 1/2 (9.75 + 13) =
on the present motor
7500 in this instance
cient, gives 1750 turn
= 180 feet per ohm = #
at 0.913 lbs per ohm
There will be 57 x 5.5 =
of length = 28.5 sq. in
be 7/16" thick + 3/16" for
The weight of copper on
or on 4 cores 88 lbs.
The total weight of copper

Modifications introduced into the Magnetic arrangement of the No1 Experimental Motor.

The cross section of one of the field-magnet core is 215 sq. cms.
By arranging the magnets sideways, as in the Continental motor, it will be necessary to double this cross section or 430 sq. cms.
This would in a circle be 23.14 cms, but as there is no room for this, an ellipse 12" × 7" (30.5 × 17.8) is almost sufficient, so that the outline of this ellipse will be distorted outwards. Allowing for winding space, the ext: dimensions would be 15½" × 10½" (39.36 × 26.67) Taking the mean (33) and the core length 11" (27.9), the surface = 33 × 3.14 × 27.9 = 28,90 sq. cms., allowing 2 ampères at 500 volts = 250 Watts = 11.5 sq. cms per Watts. It is therefore required to find the winding for 2 ampères @ 500 volts. The mean length of one turn will be ½(9.75 + 13) = 11.4" × 3.14 = 3'. The no: of ampère turns on the present motor cores is 2500 × 2.5 = 6250. Allowing 7500 in this instance as margin of safety for longer magnetic circuit, gives 3750 turns = 11,250' of wire offering 62.5 ω hot. (= 180 feet per ohm = #19 B.W.G. 0.042". + 62.5 ω of this wire at 0.913 lbs per ohm = 57 lbs. per core + 4 cores = 228 lbs.
There will be 57 × 5.5 = 313.5 c.ins: of winding space in 11" of length = 28.5 sq. in. At 36" of circumference this would be 7/8" thick + 3/16" for copper = 1 1/16" say 1 1/4 of winding space.
The weight of copper on the iron will be 3/16" × 11" × 30.6" × 0.33 = 22 lbs or on 4 cores 88 lbs.
The total weight of copper on the field magnet will thus be 316



2) Revision of armature winding for higher electrical efficiency.

Let $w = 42 \times 4.9 = 2058$ then the diam: of cond: wire is $0.1814 \div 7 = 0.0226''$ and this with 0.010 gives 0.016 wire = #27 B.W.G.

$2058' \times 0.4 = 823.2' \times 0.044\,\omega = 32.93 \div 4 = 8.2\,\omega$ cdl.

The speed will be with this winding (running light)

$$\frac{110 \times 10^3}{1.53 \times 10^8 \times 2.06 \times 10^3} = \frac{110}{3.15} = 34.9 = 2100 \text{ per min.}$$

3) Let $w = 42 \times 6.4 = 2688$ then the diam: of cond wire is $0.1814 \div 8 = 0.0227$ and conductor 0.013 = # 29 B.W.G.

$2688' \times 0.4 = 1075' \times 0.064 = 71.7 \div 4 = 18\,\omega$ cdl.

The speed with this winding will be (running light)

$$\frac{110 \times 10^3}{1.53 \times 2.69 \times 10^3} = 26.7 = 1600 \text{ per min.}$$

On completion 21st Oct. res: of armature 7.15 @ 20°C.

Weight of armature body + spider	5. 15¾ cq
" " " winding	15 cq
" " " complete	4 11 3
Total Weight of machine - without base or pulley	27 lbs. (nett)

Diam: of field core 4.75 or 1.875" Area 17.8 sq. ins. B = 18,500

Electromagnetic Design for a small Edison Motor of new type, bipolar gramme-ring, with pacinotti teeth. (132)

Power 150 Watts: To operate between 100 + 125 volts at mt. Taking 125 volts as normal in what follows:-

Speed 2500' per min: at periphery = 1250 lines. (15.9 ins. = 26.5 per sec)

Dimensions of armature. Iron body

External diam: 6" (15.2) External diam: 4¼" (10.2)

Breadth: between 18.85 (47.9) edges of grooves 1" (2.54) (32.05)

Entrefer 3/64" on each side (0.119)

42 grooves ℄ apertures. Walls of grooves parallel.

Winding calculation.

The cross section of iron is $6.45 \times 2 = 12.9$ sq. ins. and the density permissable 12,000 = 152,800 = φ.

$\varphi w = 125 \times 10^8 \quad \therefore w = \frac{125 \times 10^8}{1.53 \times 10^8 \times 26.5} = 3.08 \times 10^2$

$w = 3080$ in all

in each groove 73.4. The nearest square to this is 81. $\frac{18.85}{84} = 0.224$ = breadth and depth of groove. allowing 0.020" for body insulation leaves 0.184 for wiring breadth = 0.0205 for diam of 1 wire in 9 turns 0.011" wire # 29 B.S. d.c.c. allowing 0.009" for covering = 127 cmil = 254 cmil total capacity = 1.27 amp. at 200 cmil per amp. = 127 to 156 Watts according to voltage.

Magnetic circuit.

The surface presented by a single tooth is $\frac{0.224 + 0.171}{2} \times 0.150$ = 0.97 sq. ins. Supposing the covered on each side gives 28 sq. ins. The reluctance of this will be

$\frac{0.119}{28}$ at each polar surface =	0.00425
	0.00425
Identity ins. of polar extension × section 12	0.003
1B ins. of armature section 6 ÷ 2	0.0085
Total	0.013 Rects.

Flux needed is 152,800 allowing for leakage and any discrepancies 305,600 ∴ MMF = $305.6 \times 10^5 \times 1.3 \times 10^{-2} = 3.97 \times 10^3$ = 3160 A.T.

Allowing ½ amp. the res: of the field coil will be 1000 ω and there will be 31,600 turns. The mean turn will be $\frac{1.85 \div 3}{2\pi} \pi = 0.616' \times 31,600 = 20,060'$ for 1000 ω = 20 ft per ω = # 28 B.W.G. @ 0.0113 lbs per ω = 1143 lbs. in all. 0.014" when covered = 0.019" and 0.020 As this occupies too much space, take the entrefer as 1/32" on each side. This will reduce the reluctance to 0.01 Rects. the MMF 6.3×10^3 = 1600 A.T. = 16,000 turns of ½ amp = 1000 ω. The mean turn being 0.616 feet the 16,000 ω, 10,240' for 1000 ω = 10.24 ft per ω. # 31 B.W.G. 0.010" = 2.93 lbs in all. or # 30 B.S. 0.010" 2.96 lbs. in all.

The mean turn on the armature is 0.4' and there are 3080 turns = 1232' of # 29 B.S. @ 8.1×10^{-3} ω per ft = 100 ω ÷ 4 = 25 res. of armature. = 3.04×10^{-4} lbs there will be 4.73×10^{-1} lbs. ½ lb.

If an insulation of 0.005" were allowed for this wire on the armature the diam of copper would be increased from 0.011 to 0.015" and the capacity of the machine doubled.

Measurement of the mean thickness of a coating of rust on a mass of iron wire.

1st October. Microscopic measurement. 0·01" stage micrometer = 3·00 mm.

1st sample	rusted diameter	28·93 mm = 0·0320	cleaned diam.	27·93 mm = 0·0310
2nd	-	28·40 = 0·0316	"	27·55 = 0·0304
3rd	-	27·93 = 0·0310	"	28·05 = 0·0316
4th	-	28·85 = 0·0321	"	28·09 = 0·0311
5th	-	29·10 = 0·0323	"	28·10 = 0·0312
	Sums	143·11 = 0·1590	"	139·43 = 0·15553
	Means	28·62 = 0·0318	"	27·886 = 0·03106

Mean Difference = 0·00074

- Thickness = 0·00037

On the Cost of Power necessary to keep a Large Vessel's Hull clear of weed and rust by electrolysis.

A large vessel 800 feet long and drawing 30 feet would probably expose 370,000 square feet maximum surface. Allowing 1 ampère per sq. foot and 7 volts = 490,000 Watts say 500 kwts. @ $15 per ann. = $7500 annually.
One amp. hr. dissolves 0·7 grms iron. and 370,000 = 49,000 grms hourly = 108 lbs or 2540 lbs daily = 1·27 tons = 460 tons yearly @ $30 per ton = $13,800. Total cost $17,500 excluding labor and interest on plant.

On the Resistances needed for Feeder Equalisers at Ogden Mill

The normal current in the 6 machines is 30 ampères at 120 volt = 3·67 ω all told, and it is desired to have a box in circuit with each such that at 120 or 125 volts the current can be varied from 25 to 35 ampères.

At 120 volts	25 amps	means	5·2 ω	
" 110 "	35 "	"	3·14 ω	
		Difference	2·0.	

In 36 resistances of 0·33 ω each = 0·05 ω in multiple

To break the circuit of any one machine a resist. box will be needed from 0. to 50 ohms. in following steps

	0·1	0·2	0·3	0·5	0·7	1·0	1·5	2·0	3·0	5·0	10·0	20·0	50·0
Individual step	0·1	0·1	0·1	0·2	0·2	0·3	0·5	0·5	1·0	2·0	5·0	10·0	30·0
To carry	35	"	"	"	"	"	20	"	"	15	10	"	5

6 Feeder equalizers and 2 Breaking boxes will be needed.

Basis of Determination.

113 Electromotors each pulling one trailer.
Double track everywhere except on Chambers St. 1700 ft.
Edison Motors. Double trolley wires
20% drop maximum. No feeder.
Minimum p.d. in main 500 volts. Maximum at Station 625.

Weight of Electromotor & trailer loaded 15 tons.
@ 20 lbs per ton = 300 lbs, 5 miles per hr. = 3600 ft lbs per sec.
= 6.5 H. mechanical = 10 ampères @ 500 volts = 20 ampères @ 50% η

Basis of model.
Single track with all cars on it and double conductivity.
All resistances are 1/10 times as great per mile on the model as the actual. Mean P.D. 562 volts 20 amp = 28w
Car model are all 2.8w each.

Resumé of Conductors

Diameter Inches	B.M.E.	Wt: per foot. lbs	Length Wire feet	Total Wt lbs.	Cost @ $0.28 per lb
0.625"		390,600	1.204	294,200	354,200	88,540
~~.5~~"		250,000	0.77	66,000	50,820	12,710
0.425	000	180,625	0.5563	189,940	105,700	26,430
0.380	00	144,400	0.4448	29,760	13,240	3,310
0.34	0	115,600	0.35	25,000	8,750	2,190
0.238	4	56,640	0.1715	22,860	3,920	960
				627,760	536,630	134,140

STREET RAILROAD DATA.

Abstracts from a thesis by L.W.Healey, and J.W.Cowles gradu
of Cornell, written May 1890. From tests made on the system
at Scranton Pa. Partly worked with Sprague, and partly with
T . H . cars. Running since 1886K. Station 2 miles from cen
of city beside a culm-heap which is used with special grates
for fuel at ten cents per ton. The plant has five horizonta
tubular boilers rated at 125HP each, 3 A&S engines 260 revs
15 1/2 x 15" driving each a pair of Edison 500 volt,100 amp
dynamos by direct belting. 30 cars each fitted with 2-15HP
motors. the system is the single overhead trolley wirewith
seven feeders, and rather hilly district.There is mention of
a ground conductor.Cars run from 4.30 to 24 oclock daily.
Water from city mains. Electrical readings during test taken
every fifteen mins. Grade tests made with a special car.
Weight of this car not given and no mention made of weight o
any cars. Power tests made by Prony brake on one motor, jack
Average boiler press 88.45lbs. Temp. 246°f duration of test
20 hours.Average quality of steam 97.15%.Water evaporated pe
lb. of combustible from and at 212° 9.11lbs.Average comm.HP of
boilers 278.Avr. Friction card of #1 engine dynamo open cct
12.6,ditto #2,#3 10.2

Max. I.H.P.	411.9	Max. EHP	314.2
Min. I.H.P.	10.28	Min E.H P.	5.16
Avr. IHP	257.7	Avr. EHP.	196.7

Avr. comm eff.of dynamos ~~G=28~~ 92, and of system0.76 down t
feeder K..34.5 lbs. of water per IHP per hour or 44.86lbs. pe
EHP 4.08 lbscombustible per IHP per houror 5.34 lbs. combus
ible per EHR per hour. 30 cars Total car milage 7069
Passengers 10,150 Avr IHP per car 8.59 Avr. EHP 6.56:295 lbs
of water per car hour, 35 lbs of combustible or 56.2 lbs. of
culm per car hour. PD. on car varied from 406 to as low as
298 in few cases. Highest grade 9.75%, absorbing 82 amp. at
408 voltsboth Sp, and TH. Speed on level 13.6 m.p.hr. TH wi
24.6 amp: at 367 volts or 12.1EHP and 17 m p hr. with Sp.
17.0 amp at 390 volts or 8.9EHP. Avr. Insulation of system
by Wh.br. 764 ohms. Ratio of TH gearing 9.41 of Sp. 11.7
The brake eff. of the TH. is 37% at 12.8 m p hr. with 1.74
BHP. up to 85% at 8.3 m p hr. at 8.85 BHP. The Sp. eff. was
56% eff. at 13.6 m p hr. 2.0BHPup to 90% eff. at 6.6 m p hr.
and 7.1 BHP.

Abstracts from the report of a test made by Mr. C. F. Hamilton, on the effect of introducing the equalizer field coil to the Sprague Car, in Scranton Pa. 1st. Oct. 90

A car was operated with a light load four times along the same section, and the currents in the two motors measured at the same instants and at regular intervals of time, using two ammeters. The pressure averaged 375 volts on the car, and the road was rough and grades steep. A large number of readings were taken but the general means only are here given.

Up run. Motor A 11 amperes Motor B 17.5 amperes.
Down run 14 12

This was without equalizers, and words up & down refer only to direction. The rear motor on a grade is stated to take the greater current.

Oct. 2nd. Car 3 without equalizer. Level road and even load
Down run Motor A 22 amperes. Motor B. minus 11 amperes.
Up run 18 minus 1.7
Motor A run alone, B cut out of circuit.
Up run A 15 amperes. Down run A 8 amperes
Motor B run alone, A cut out of circuit.
Up run Motor B 14 amperes, Down run Motor B 9 amperes.
The opposition of the two motors took place on and after the 3rd. notch of the switch.

Same car Oct. 4th. equalizer in place but not yet in circuit.
Up run Motor A 20.8 amperes. Motor B 0 amperes.
Down run 15.5 minus 1.4
Equalizer next employed, no other change.
Up run Motor A 16.9 amperes. Motor B 3.5 amperes.
Down 12.7 2.3
Oct. 8th. Car #2 First without equalizer
Up run Motor A. 17.5 amperes. Motor B. 7.9 amperes.
Down 17. 6.8
Equalizer applied, no other change.
Up run Motor A 12.9 amperes. Motor B. 9.4 amperes.
Down 11.2 5.7

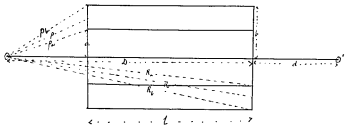
The general mean of all results indicates that the average current taken by the car was 23 amperes without equalizer, and 19.6 amperes with it.

Extracts from a memorandum by Mr. J. H. Vail on Milwaukee

Estimated weight of car and trailer is:- 16 ft. car 60001bs Truck 2000, Motor and fittings 5000, 60 passengers 8400 and trailer 16000 making a total of 37, 400 lbs. or 18.7 tons. Cars are expected to make 10,-12,-14,-and even up to 20 miles per hour. 10 or 12 miles not unusual when car leaves center of city. Estimates current per car 35-40 amperes. Double trolley wire system very expensive. . Only present paying lines in States use single trolley. Under existing practise the trolley wires are supplied from the subfeeders every 400 feet.

On the Determination of a Conducting Trolley Wire System for Milwaukee Wis.

No.	Street	Track Length	Track feet	Trolley feet	Grade	Motor R. feet	C. Mile	Motor R. per	Total W.	Max No. Car	Feet	Total cost
									lbs.			$
1	Center	5.88	2,940	11,760	0.025	0.01657	180,625	0.171	6,540	1	16	1,640
2	Wright	9.25	4,620	18,500	0.025	"	"	"	10,280	2	13.5	2,370
3	Walnut	16.75	8,380	33,520	0.025	"	"	"	18,650	5	13.5 9	4,660
4	Chestnut	14.88	7,440	29,760	0.022	0.0213	144,400	0.215	13,240	6	12.5 8.5	3,310
5	Third	3.3	1,650	6,600	0.014	0.05267	56,600	0.548	1,132	1	15	280
6	Eighth	20.0	10,000	40,000	0.025	0.0132	250,000	0.126	39,800	6	15 11.2	7,700
7	Third	13.75	6,880	27,500	0.025	0.01657	180,625	0.171	15,300	4	11	3,820
8	"	6.0	3,000	12,000	0.028	0.0132	250,000	0.126	9,240	2		2,310
9	Richards	10.0	5,000	20,000	0.025	0.01657	180,625	0.171	11,130	3	9.15	2,780
10	Murray	19.75	9,880	39,500	0.025	0.01657	180,625	0.171	21,970	1	11 16	5,490
11	Racine	1.5	750	3,000	0.014	0.05267	56,600	0.548	514	1	9.15	120
12	Brady	13.5	6,750	27,000	0.025	0.01657	180,625	0.171	15,010	4		3,750
13	Dock	1.88	940	3,760	0.025	0.01657	180,625	0.171	2,090	2		520
14	State Market	7.0	3,500	14,000	0.028	0.0132	250,000	0.126	10,780	1		2,700
15	Broadway	4.6	2,300	9,200	0.035	0.00843	390,600	0.0807	11,070	3		2,770
16	Kinnickinnic	36.25	18,120	72,500	0.035	0.00843	390,600	0.0807	87,200	14	21	21,830
17	Mason	2.5	1,250	5,000	0.025	0.01657	180,625	0.171	2,780	1		700
18	Michigan	3.25	1,630	6,500	0.014	0.05267	56,600	0.548	1,120	2		280
19	Clybourn	1.88	940	3,760	0.014	0.05267	56,600	0.548	645	2		160
20	Huron	1.75	880	3,500	0.035	0.00843	390,600	0.0807	4,215	2		1,050
21	Sycamore	1.5	750	3,000	0.014	0.05267	56,600	0.548	514	-		130
22	Reed	17.25	8,630	34,500	0.035	0.00843	390,600	0.0807	41,500	10		10,380
23	National Ave.	35.25	17,630	70,500	0.035	0.00843	390,600	0.0807	84,900	8	20 17.5	21,220
24	Washington	9.0	4,500	18,000	0.035	0.00843	390,600	0.0807	21,680	2		5,420
25	Greenfield (W)	6.75	3,380	13,500	0.020	0.0258	115,600	0.268	4,725	2	12.5	1,180
26	" (E)	9.0	4,500	18,000	0.035	0.00843	390,600	0.0807	21,670	4		5,420
27	11th Muskego	14.0	7,000	28,000	0.035	0.00843	390,600	0.0807	33,700	3	14	8,430
28	Forest Mitchell	17.0	8,500	34,000	0.035	0.00843	390,600	0.0807	40,930	4		10,230
29	Windlake	3.0	1,500	6,000	0.035	0.00843	390,600	0.0807	7,220	1		1,800
30	"	5.75	2,880	11,500	0.020	0.0258	115,600	0.0807	4,025	2		1,010
31	Chamber	3.4	1,700	3,400	0.025	0.01657	180,625	0.171	1,890	-		470
		315.57	157,820	627,760					536,560	101		134,140



Mathematical Determination of the Difference of Electromagnetic Potential between two points on the axis of a uniform and homogeneous compound solenoid situated outside its terminal planes and equally distant in opposite directions from its centre of figure. (13)

Let ρ be the current per unit area of longitudinal section (abcd). Then the potential at O of an elementary ring $dr\,da$ of radius r and dist. a

$$dV = 2\pi\rho\, da\, dr\left(1 - \frac{a}{\sqrt{a^2+r^2}}\right) \qquad (1)$$

Consider any cylinder of radius r, and integrate from $a = d$ to $a = D$

then
$$\frac{dV}{2\rho\pi dr} = \int_d^D da - \int_d^D \frac{a\,da}{\sqrt{a^2+r^2}} \qquad (2)$$

$$= (D-d) - \sqrt{D^2+r^2} + \sqrt{d^2+r^2} \qquad (3)$$

$$\therefore \frac{dV}{2\pi\rho} = l\,dr - dr\sqrt{D^2+r^2} + dr\sqrt{d^2+r^2} \qquad (4)$$

Integrate this from $r = a$ to $r = b$.

$$\frac{V}{2\pi\rho} = \int_a^b l\,dr - \int_a^b \sqrt{D^2+r^2} + \int_a^b \sqrt{d^2+r^2} \qquad (5)$$

$$= l(b-a) - \left[\frac{r}{2}\sqrt{D^2+r^2} + \frac{D^2}{2}\log\left(r+\sqrt{D^2+r^2}\right)\right]_a^b$$
$$+ \left[\frac{r}{2}\sqrt{d^2+r^2} + \frac{d^2}{2}\log\left(r+\sqrt{d^2+r^2}\right)\right]_a^b \qquad (6)$$

Abbreviating as in figure
$$\frac{V}{\pi\rho} = 2l(b-a) - \left\{b R_b + D^2\log_e(b+R_b) - a R_a - D^2\log_e(a+R_a)\right\}$$
$$+ \left\{b\rho_b + d^2\log_e(b+\rho_b) - a\rho_a - d^2\log_e(a+\rho_a)\right\} \ldots \qquad (7)$$

The potential of the coil at O′ must be numerically equal to this with the opposite sign, increased by $4\pi\rho(b-a)$

$$\therefore \frac{V'}{\pi\rho} = +2l(b-a) + \left\{b R_b + D^2\log_e(b+R_b) - a R_a - D^2\log_e(a+R_a)\right\}$$
$$- \left\{b\rho_b + d^2\log_e(b+\rho_b) - a\rho_a - d^2\log_e(a+\rho_a)\right\} \qquad (8)$$

$$\therefore \frac{V'-V}{2\pi\rho} = b(R_b-\rho_b) - a(R_a-\rho_a) + D^2\log_e\left(\frac{b+R_b}{a+R_a}\right) - d^2\log_e\left(\frac{b+\rho_b}{a+\rho_a}\right) \qquad (9)$$

For a lesser degree of accuracy, let $R^2 = D^2 + \left(\frac{a+b}{2}\right)^2$ $\rho^2 = d^2 + \left(\frac{a+b}{2}\right)^2$

Then $V'-V = 4\pi\rho(R-\rho)$, or if Γ be the current in the Rolls
N = total no. of turns

$$V'-V = 4\pi\Gamma N\left\{1 - \frac{l-(R-\rho)}{l}\right\} \qquad (11)$$

$$\text{or} \quad = 4\pi\Gamma N\left\{\frac{R-\rho}{l}\right\} \qquad (12)$$

As an instance, take the following case

$l = 20$, $d = 5$, $D = 25$, $a = 2$, $b = 4$, $\Gamma = 1$, $N = 4{,}000$

$\therefore R = 25.18$, $\rho = 5.8$, $R_b = 25.32$, $\rho_b = 6.44$, $R_a = 25.08$, $\rho_a = 5.39$

The ordinary formula gives $(4\pi\Gamma N)$ $V'-V = 50{,}280$

" (12) " 48,730

" (9) " 48,700

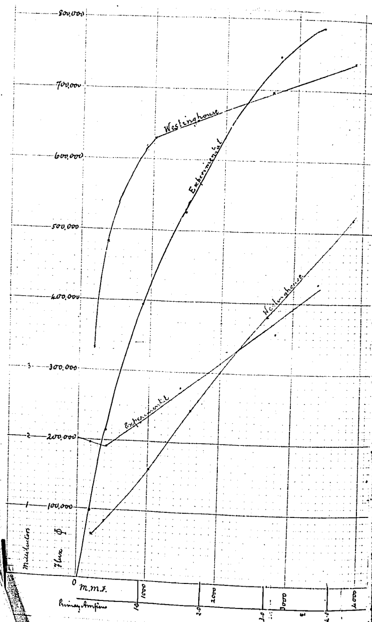
If the points are not equidistant from the midplane along the axis let d_1 and d_2 be their distances from the terminal planes respectively.

$$\frac{V'-V}{\pi\rho} = b(R_{1b}+R_{2b}-\rho_{1b}-\rho_{2b}) - a(R_{1a}+R_{2a}-\rho_{1a}-\rho_{2a})$$
$$+ D^2\log_e\left(\frac{b+R_{1b}}{a+R_{1a}}\right) + D^2\log_e\left(\frac{b+R_{2b}}{a+R_{2b}}\right)$$
$$- d_1^2\log_e\left(\frac{b+\rho_{1b}}{a+\rho_{1a}}\right) - d_2^2\log_e\left(\frac{b+\rho_{2b}}{a+\rho_{2b}}\right) \qquad 13.$$

0·1981	0·1999	0.0018	1	~~0·000~~3.24 × 10^-6	3·24
	0·1988	0·0007	2	~~0·000~~0·49	0·98
	0·1975	0·0006	4	~~0·000~~0·36	1·44
	0·1976	0·0005	2	0·25	0·50
					6.16 × 10^-6 √ = 2·

$0·3894 \times 2·482 \times 10^{-3} = 0·967 \times 10^{-3} \div \sqrt{9} = 0·32 \times 10^{-3}$

0·0003



Obach Galvanometer Constant

Single Ring) 6th October 90. (Frazer obs.)

Determination with the aid of a silver voltameter in 3 trials and " " " " " copper " " 1 " "

No.	Voltam.	Weight Before	observed After	Gain	Loss.	Mean	Time secs	Accepted transfer per sec	No: of tangent readings	Mean	Mean calculated current amps.	Deflns: per amp:	Weight estimated	General Mean	Probable error
1	Ag:	13·1598 12·2560	13·8085 11·5834	0·6487	0·6726		300	2·1623 × 10^-3	31	0·3866	1·934	0·1999	1	0·1999	
2	"	13·8085 11·5834	13·0253 12·2425	0·6591	0·7832		300	2·197 × 10^-3	31	0·3906	1·965	0·1988	2	0·3976	±0·0003
3	"	12·8474 11·6695	12·1885 12·3205	0·6510	0·6589		300	2·1963 × 10^-3	31	0·38807	1·9645	0·1975	4	0·7900	
4	Cu	9·7621 9·6820	10·1378 9·3028	0·3757	0·3792		600	6·32 × 10^-4	40	0·38075	1·927	0·1976	2 9	0·3952 1·7827 0·1981	

Result :– Tangent deflection per legal ampère 0·1981 ± 0·0003

Test of Edison Experimental Transformer # 3.

The dimensions of this instrument are similar to those given on page 130. but the exterior iron wire has very thin rust coating. see p 133. The interior core however is similar in condition to the previous one.

No.	E.M.F.	Value	Capy	Q	·divs	No. of throws ×	Q per div.
	2 C.C. @16°C	2·8738 × 10^8	1 ^{F} × 10^-15	2·8738 × 10^-7	114	2·521 × 10^-9	4

No.	Std. G.	Obach	Amp.	Turn	M.M.F.		No. of throws	Mean	Res: in cct.	Res. of G. cct.	Turns	Q singly	Φ	M/Φ Induct.
1	16°		0·216	720	195·6		4	91	25,000	30,250	35	3·278 × 10^-9	9·915 × 10^4	1·97 × 10^-3
2	30°·40'		0·447		404·7		4	196	"	"		7·058	2·135 × 10^5	1·90 "
3	52°·30'	0·195	{0·982 0·985.}		891·8		3	198	50,000	55,250		7·130	3·949 × 10^5	2·264 "
4	"	0·32	1·616		1463		3	139	100,000	105,250		5·005	5·269 "	2·778 "
5		0·60	3·03		2743		3	197	"	"		7·094	7·466 "	3·673 "
6		0·74	3·74		3386		3	208	"	"		7·49	7·884 "	4·293 "
1		0·84	4·24	720	3839		4	195	"	"	35	7·022	7·392	5·192 "
2		0·58	2·93		2652		4	184	"	"		6·626	6·975	3·802 "
3		0·352	1·78		1611		4	173	"	"		6·231	6·558	2·456 "
4		0·22	1·11		1005		3	161	"	"		5·798	6·292	1·597 "
5	30°·15'	#	0·439		397·5		3	127	"	"		4·573	4·814	0·8256 "
6	17°·45'		0·241		218·2		4	88	"	"		3·17	3·337	0·654

Test of Street Car low volt motor running as a dynamo. 9th Oct. 90 See p. 60 + 17 Book II.

920 revs: 12 volts p.d. subsequently 950 revs: 7.7 volts 3.6 amp. in field. The armature bolts of the machine were subsequently found to be broken and to renew them would necessitate disconnecting the commutator. The machine was consequently discarded.

Test of Alternating & Continuous current Machine

Speed 1470 revs: 5.3 amp. through field. Bender defln 136° equivalent to volts with continuous current.

Test of the three Standard Meters.

The three meters were connected in series, and a current of 10 amp. passed through them for about 40 hours.
The resistance of these meter circuits are:-

Number		Res. of Shunt Light Ohms	Temp.	Res. of Arm'd Light Ohms	Temp.	Ratio Arm'd to Shunt	Mpgs. transfer for amp.	Transf. Res. per megger transfer
Book II p. 152	1	0.0993	23°C.	98.05	21°C.	1017.6	1.2028	0.8344
"	2	0.09945	22°C	98.03	22°C.	1015.9	1.2048	0.8300
Book I p. 47	3	0.37614	23.3°C	514.3	19°C.	1374.3	0.8906	1.1228

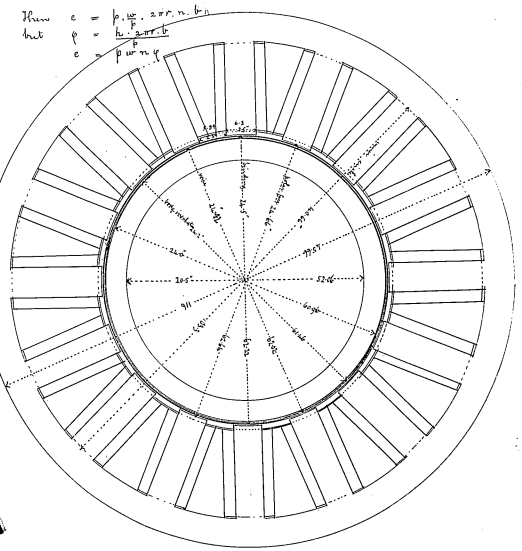
No. of plate	Weight before test	Weight after test	Gain	Loss	Complete gain	Accepted transfer	Amp. hrs.	Mean
Meter 1 3	49.316	48.842		0.474	0.025	0.487	404.9	
4	50.169	50.669	0.500					
" 2 5	49.952	50.456	0.504	1	0.022	0.488	405.0	405.4
6	49.396	48.914		0.472				
" 3 7	50.465	50.107	0.	0.358	0.008	0.362	406.4	
8	49.781	50.147	0.366					

Let b be the breadth of armature
" w " " no. of wires all round
" p " " " poles and segments
" h " " mean field
" r " " radius
" n " " no. of revs. per sec.
" e " " emf.

Then $e = p \cdot w \cdot 2\pi r \cdot n \cdot b \cdot h$

but $p = \frac{h \cdot 2\pi r \cdot b}{\phi}$

$e = \phi \cdot w \cdot n \cdot p$



Edison Experimental Alternator 700 lamps Section at right angles to axis

Scale 1/6

PARTICULARS OF EDISON EXPERIMENTAL ALTERNATOR NO. ONE.

Gramme Ring armature, and 16 poles.

Power. 60 Kilowatts. 50 amperes mean current at 1200 volts mean EMF. or of sufficient capacity to operate 700 lamps of 50 watts each at an intermediate loss of 30 %.

Speed. 1200 revs. per min. or 20 per second. peripheral speed 7700 feet per min. or 128 feet per second.

Frequency. 16 alternations or 8 per rev. , 160~ per second 9600~ per minute, or 19,200 reversals.

Dimensions.	Diam. of armature body. internally	20.5"
	externally	24 "
	over insulation	24.2"
	over conductor,	24.42"
	over binding	24.5"
	Diam. of polar face circle	24.67"
	field frame internally	40.67
	externally.	45.67
	Diam. of iron wire recommended for arm.	0.032"
	Breadth of armature	10. "
	Clearance	0.084"
	Entrefer	0.33"
	Width of poles	2.5"
	Breadth of poles	10. "
	Thickness of pole plates	0.125"
	Distance between adjacent polar ends	2.33"
	Number of plates composing fields	640
	Weight of iron in magnets	1620 lbs.
	Weight of iron in armature	2951bs.

Armature. Body insulation of 0.1" all round.
Winding 512 turns of No. 18 AWG. 0.095" dcc. to 0.110" in one layer of 16 segments. , segments being reversed in succession. The two adjacent ends to be carefully separated and insulated.
Max. EMF. per segment 150 volts. or 2400 volts in all
mean EMF. 1530 at full load. Area of wire 9025 c mn giving 180 c mils per amp. mean, and 163 c mils per amp. effective, at full load.

Weight of conductor	28 lbs.
Length of conductor	1025'
Resistance of conductor hot	1.3 ohms.

Field. Magnetic Circuit.

Flux through poles estimated	2,000,000
Leakage estimated	500,000
Induction density in magnets	12,400
in armature iron	9,300
in armature space.	6,650
allowing space factor of 0.7	0.017 lucts
Estimated reluctance of circuit,	

Magneto-motive Force estimated to be needed	12,800
Ampere-turns	10,180
on each core,	5,090
Current in field magnets	18.67amp.
Number of turns on each core,	273
Surface of spool	1400sq. cms.
Energy per sq. cm.	0.01 Watt.
Field winding 34 lbs. of # 10 AWG. 0.134" sec. or 630 ' in 273 turns on each core of six or perhaps seven layers.	
Total depth of winding above iron	1.0"
Resistance per core cold	0.35 ohm
hot	0.4ohm.
Total res. of fields in series hot	6.4 "
P.D. maintained by exciter on field	120 volts.
Standard Size of Edison dynamo exciter #1.	

Power absorbed in field magnets full load 2240 W.
Power absorbed by exciter in maintaining 2040
Power absorbed in mechanical friction 2000
Hysteresis estimate 2560
Foucault estimate in field and arm. 440
Power lost in armature resist. full load 2800
Power estimated for running light 7000
" " " " full load 11,480
Power estimated for at full load 60,000
Total estimated commercial efficiency of dynamo and exciter at full load. 84 %

On the outlines of a design for a 600 light Alternator with a frequency of 125 ~ per sec, 6500 ft. per min. peripheral velocity, and 30" ext: ann: diam.

With 8 poles there will be 4 periods per revolution, and consequently there must be 31.25 revs: per sec: ~~or 65~~ 1875 revs: per min: @ 6500' per min = 3.28' per circum: = 12" diam.

Taking 20 poles, and 30" circumference, for 160 ~ per sec. there must be 16 revs: per sec, or 960 per min, and 2.5' diam. = 7.85' circum: = 7.540' per min: 94.2" circum = 4.7" per magnet & clearance.

The e.m.f. to be generated must be 1500 volts allowing for inductance. At the top of the curve if it be sinusoidal the emf must be 1.6 × 1500 = 2400 volts, or 120 volts per segment.

So that
$$120 \times 10^8 = \varphi \times 16 \times w$$
$$\varphi w = 7.5 \times 10^8$$

With 16 radial poles, there will be 1200 revs: per min: or 20 per sec. for 160 ~. The ext: diameter being 24", the circumference will be 6.28' = 75.4". Allowing for a total e.m.f. of 2400 volts, each segment will be generating 150 volts, so that
$$\varphi w = 1.5 \times 10^{10}$$

Suppose 10% of the available exterior armature surface taken up for insulation purposes, the diameter of the interior will be say 20" circ: 62.8" − 6.3 = 56.5. The current carried by the machine will be about 444 amp: at full load, or 88,000 cmil @ 200 per amp. = # 13 B.W.G. 0.095" bare = 0.110" covered. There will be room for 582 turns of this wire or 328 per segment.

$$\therefore \varphi = 1.5 \times 10^6$$

Allow a density of 6500 in the armature space = 230 sq. cm or half of this on each side = 115 sq. cms: of cross section. With a depth of 1.75" (4.45) the breadth = 25.8 or 10".

Allowing a density of 15,000 in the iron there must be 150 sq. cms in the polar projections. The polar face circumference being 77.46", the face of each pole allowing an equality of pitch is 2.42" = 6.15 cm × 25 = 150 sq cms.

The embrifer is as follows:— Body) insulation 0.1" Wire 0.11", binding wire 0.034", Clearance 0.05" Total 0.33" = 0.85 cm.

The reluctance is $1.7 \div \frac{200}{2} = 0.017$ unit, and the m.m.f. required to drive $\frac{1.5 \times 10^6}{2}$ lines through the circuit will be 1.275×10^4 A.T. or 5,975 A.T. on each spool. The spool surface is = 10,450 20 × (25) × 2 = 11,000 sq. cm, and allowing 20 Watts per sq. cm. gives 70 Watts per spool, the e.m.f. on each spool will be $\frac{120}{16} = 7.5$ volts or 9.3 amp. = 644.0 turns. The length of each turn will be approximately 2.3 ft. so that the total length will be 1470', the res: of which must be 0.806 ω. say 0.7 ohm = 2100' per ohm. = # 9 B.W.G. and 1470' @ 0.066 lbs. per ft. = 97 lbs.

Allowing 0.010 Watts per sq. cm, from the spool surface gives 110 W. 18.67 amp. = $\frac{5000}{18.67}$ = 273.0 turns × 2.3 ft = 628 ft. offering 0.86 = 1800 ft per ω = # 10 B.W.G. + 628' × 0.0584 = 34 lbs × 16 = 544 lbs in all.

The diam: of this wire is 0.134 = 19,000 cmil = 950 cmil per amp.
" " " covered - 0.150 dia 7.7" = 50 wire in each layer, and 5.5 layers deep = 0.73" of wire say 0.9" in all.

45.7 inch = 1640
40.7 " = 1301
339 sq. in.

5 × 339 = 1695 cubic in.
+ 16 × 8 × 10.255 = 3200 " "
+ 2.558 × 2.506 = 500 " "
5400 " " @ 0.30 = 1620 lbs.

24.0" area 452.4
20.5 330.1
122.3 sq. in.

10 × 0.8 × 8.2 ×
= 978.4

Field winding revision.

To send 750,000 lines through the magnetic circuit, a MMF. of 15,100 will be needed, this allowing for a reluctance of 0.017 in the air space, and 18% above 0.03 in the armature.
A.T. 12,022 or 6,011 on each core = 322 turns × 18.67 amp.
322 turns @ 2.3' mean turn = 740' of wire offering 0.35 ω cold
= 2114' per core = # 9 B.W.G. 0.148
award 0.160

In 7.5" there will be 45 turns and in all 7 layers, occupying 1.17" or with spool say 1.3" = depth.
740' @ 0.0663 lbs. per ft = 49 lbs or 784 lbs. on all cores.

Particulars of Edison Experimental Alternator.

Power: 60 Kilowatts 50 amp. mean current @ 1200 volt mean emf.
16 poles, gramme ring armature.

Speed 1200 revs. per min, 20 per sec. = 7700 ft per min:
or 128 ft. per sec. at periphery.

Frequency 16 alternations or 8 ~ per revolution. = 160 ~ per second 9600 ~ per min or 19,200 reversals.

Dimensions

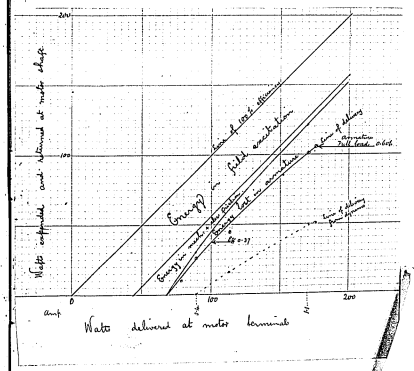
Diameter of armature body	20.5" int:		1½" drop (pressed from wire)
" " "	24" ext.		
" " " new insulation	24.2"		
" " " wire	24.42		
" " " binding	24.5		
Breadth of armature	10."		Clearance 0.08 1/16"
Diameter of iron wire # 21 B.W.G.	0.032"		
" " polar faces	24.75"		
" " inner surface frame	40.75"		
" " outer " "	45.75".		
Width of polar heads	2¾"		
Distance between polar ~~extremities~~	2¾"		
Breadth of poles	10".		
Sheet thickness of wrought iron	⅛".	150 sheets, each way.	
Volume of iron in field	5400 c.i.	1620 lb. mass	
" " " armature	978.4	294 "	
Number of plates in field	640.		

Armature. Body insulation of 0.1" all round. Extra good.
Winding one # 13 B.W.G. 0.095" d.c.c. to 0.110" 5.12 turns round in 16 segments of 32 wire each, these segments to be reversed in succession. The two ends to be very carefully separated and insulated. Maximum emf. per segment = 150 volts = 2400 volts in armature, mean emf. 1520 volts.
Area of wire 9,025 c.mil. mean area/pressure 180 at full load mean area per effective ampere 163 cmil. - - -

Fields. Mean Induction in armature space 6,650 = 9200 in iron. allowing 0.9 as net factor and 0.785 as space factor = 0.707
Cross section of armature 17.5 sq. in. = 113 sq. cm. = 750,000 ω flux
Polar flux 1,500,000 and polar cross section 2.5 × 10 = 25 sq in
= 161.3 sq. cm. induction, allowing 25% for leakage = 2,000,000/12.4 = 12,400 in iron. Field winding 273 turns of no 10. B.W.G. 0.134" in six layers of 45 turns each. Total resistance of wire 0.35 ω cold = 33 lbs. total length 273 × 2.3 = 628' × 0.052 ω = 33.9 lbs. say 34 lbs. Surface of spool only 1400 sq. cm. all spools in series = 0.24 × 16 = 6.2 ω and current 18.67 amp. needing 119.5 volts. Energy in each spool 18.67 × 119.5/16 = 140 = 10 sq. cm. per Watt. Total energy absorbed in field 2240 Watt supplied by a #1 Edison dynamo. M.M.F. of field magnet = 18.67 × 273 × 1.257 × 2 = 12,820 and the reluctance is only the entire and 10% for iron wire above this = 0.33 × 2.54 × 2/600 = 0.017 but ~~taken~~ overshot = 750,000 lines.

Armature wire. One turn = 2' = 1024 feet in all = 1.3 Ohm hot 28 lbs. wire
fall of potential mean 65 volts, effective 71 volts.
loss of energy) frictional in armature at mean full load 3200 Watts, at effective full load 3740 Watts.
Total loss of energy in resistance at full load fields and armature 6000 Watts add friction, ~~and~~ foucaults.
Hysteresis, 160 × 10,000 × 16,000 = 256,000,000,000 = 2560 Watts.
With foucaults say 3000 Watts. Friction 2800 Watts
88% Machine will absorb 8740 Watts at full load generating 60,000
" " " 7240 " " no load " 0

No	Energy in dynamo	Remarks
1	–	Current through field magnets. (145 Watts)
2	–	Motor armature uncoupled and running light (70 Watts or 30 in friction) torque 93 grms
3	–	Motor armature driving dynamo armature in unexcited field. 33.9 Watts 168 delivered
4	–	- - - - - and excitation.
5	25.5	Driving dynamo with load: stopped to excite dynamo field separately.
6	–	Current through field magnets (142.3 Watts)
7	–	Driving dynamo on open cct: through separately excited field.
8	15.4	- - - load
9	50.6	- - - - full load on motor.
10	49.9	- - - - - - - -
11	49.4	- - - - - - -
		Stopped test. Temp: of air within motor armature 40°c.



Test of the efficiency of a small ⅛ H.P. C.C. Motor.

12th October 1890.

The small ⅛ H.P. B.R.C. motor weighing 16 lbs. 11 oz. = 7570 grammes has an armature resistance cold of 16 ω and inductance of 800 kilometres with the field magnets unexcited or 736 kilometres in excited field. The field magnets have a resistance of 320 ω cold. (20°C) and an approximate inductance of 23·17 earth-quadrants. ($\frac{100000}{1000}$, 071, 3310) This motor was placed on the float of a Webb dynamometer, and connected with a small Paris ⅛ H.P. motor which it ran as a dynamo through a spiral spring. Results as follow:—

No.	Time	Revs. of pan min	machine per sec	P.D. on motor.	Shunt reading.	Amperes this motor	Energy absorbed by motor	Scale reading	Torque	Energy delivered by motor	P.D. on dynamo terminals	Sp. g. reading for dynamo 1 sec.	Amperes in dynamo test.
1		–	–	119	0.075	0.379	45.1	–	–		–	–	–
2		3200	53.3	"	0.125	0.63	75	–	–	–	–	–	–
3		"	"	"	0.131	0.661	78.7	50 @ 6				–	–
4	15.35	2850	47.5	118.7	0.207	1.045	122.3	100 @ 10 50 @ 9	300	59.80	–	–	–
5	15.40	2775	46.3	116.7	0.245	1.237	144.4	100 @ 20 50 @ 12	1950	72.85	76	2.42	0.336
6	16.00	–	–	118.0	0.065	0.358	42.3	–	2600		–	–	–
7	16.05	3025	50.4	117.0	0.150	0.763	89.3	100 @ 5 50 @ 7	850	26.4	–	–	–
8	16.09	3050	50.9	118.0	0.190	0.960	113.2	100 @ 10 50 @ 8.5	1425	44.7	110	10.30	0.140
9	16.15	2650	44.2	117.0	0.297	1.50	175.5	100 @ 30 50 @ 18	3920	106.3	83	39	0.610
10	.30	2600	43.3	"	0.291	1.47	171.9	100 @ 20 50 @ 35	3750	100.1	81.7	–	–
11	.50	2600	43.3	"	0.287	1.45	169.6	"	"	"	80.9	"	"

The results obtained are:—

	Watts
Power required to excite motor fields	42·3
" " " run armature to speed	30

The resistance of the armature hot being 18 say, the efficiency of the machine as commercially at 118 volts

$$\frac{c(118 - 18c) - 30}{118c + 42.3}$$

at 1·14 amps $c = 1.14$ this becomes $\frac{101}{176.8} = 0.598$

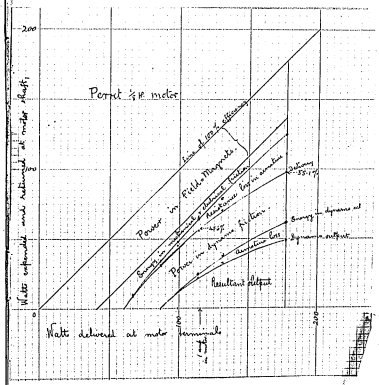
As observed it was $\frac{106.3}{175.5} = 0.606$

The general formula is

$$\eta = \frac{\left(c - \frac{c}{340}\right)\left\{e - 18\left(c - \frac{c}{340}\right)\right\} - 10}{ec}$$

2 × 3.1416 × 981 = 6166

	Intake				Calculated Loss			Output			
Time of Obn.	P.D. on motor Volts	Shunt Amps	Current through motor Amps	Energy on motor Watts	Energy in armature Watts	Calculated Friction in armature Watts	Difference	Revs. per min.	Revs. per sec.	Scale Rdg	Torque Grams
.1	123	0·065	0·328	40·4	-						
.2	122	0·097	0·490	59·9	19·4	0·4	19·0	2900	48·3	-	-
.3	121·5	0·109	0·550	66·8	26·4	0·8	25·6	2850	47·5	50 g @ 6	300
.4	120·5	0·141	0·712	85·8	45·4	~~2·5~~	~~42·9~~	2980 ?	44·7	{100 @ 5 / 50 @ 12}	1100
.5	120	0·143	0·722	86·6	46·2	2·9	43·6	2834	47·2	"	1100
.6	121·5	0·162	0·818	99·4	59·0	4·1	57·9	2808	46·8	{100 @ 5 / 50 @ 25}	1575
.7	118	0·191	0·965	113·9	73·5	7·1	66·4	2704	45·0	{100 @ 10 / 50 @ 30}	2000
.8	117	0·221	1·116	130·6	90·2	10·9	79·3	2574	42·9	{100 @ 20 / 50 @ 38}	2650
.9	116	0·307	1·55	179·8	139·4	26·8	112·6	2223	37·0	{100 @ 25 / 50 @ 50}	4400
.10	116·5	0·302	1·525	177·7	137·7	26·8	110·9	2184	36·4	"	"



Efficiency test of the ½ H.P. Perret Motor.

The Perret motor weighs 17lb 3oz is marked 2200 rev., 110 volts, 1 amp. Its armature resistance was 17.0 ω the field resistance 314 ω. The motor was flouted and connected to drive the C.-B.

Energy Delivered		Delivery: D.D. on dynamo volts	Stat. g. reading	Turns	Amperes	Energy delivered watts	Calculated Cm in amps	Remarks
	field							Field of motor excited
	90							Motor armature running light
6.8	44							- - coupled to dyn. arm.
30.3	44	92						- - - - - dyn. field excited
32.2	44	94						- - - - - load commenced
45.5	42	93	8°55′	0.1568	0.118	11.0	0.2	1.12 - - - - - - -
55.5	40	84	19°30′	0.3541	0.267	22.43	1.1	1.235
70.1	38	78	29°	0.5543	0.418	32.6	2.9	1.375
100.4	35	57	49°25′	1.1672	0.880	50.2	12.4	1.626 Full load
98.7	34	55.5	49°30′	1.1705	0.882	49.0	12.5	1.5 After one hour

The temperature on the surface of the armature after one hour's run was 64° C.

The efficiency of this motor is

$$\frac{c_a\left\{c - 18\frac{c}{360}\right\} - \frac{c_a^2}{360} - f}{cc}$$

where c is the emf at machine terminals

c_a - - current through the armature

c - - - - - - machine

f - - power in friction

$c_a = c - \frac{c}{360}$

f = a function of c and c but for moderate loads 10

$$\therefore \eta = \frac{\left(c - \frac{c}{360}\right)\left\{c - 18\left(c - \frac{c}{360}\right)\right\} - \frac{c_a^2}{360} - 10}{cc}$$

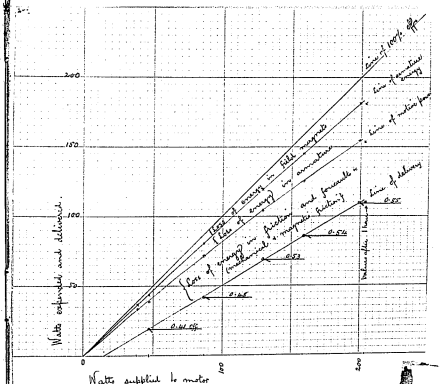
The last observation gives

$$= \frac{\left(1.525 - \frac{116.5}{360}\right)\left\{116.5 - 18\left(1.525 - \frac{116.5}{360}\right)\right\} - \frac{(116.5)^2}{360} - 10}{116.5 \times 1.525}$$

$$\frac{1.202 \times \{116.5 - 21.6\} - 32.37 - 10}{177.6}$$

$$\frac{104.1}{177.6} = 58.6\ \%$$

No. of Obs.	P.D. on motor volts	Obserd. Amp.	Amperes in motor	Energy in motor Watts	P.D. on field	Energy in field	P.D. on armature	Energy in Arm.	Mechanical loss in arm.	Difference	Revs. per min.	Revs. [illegible]
1	11·8	0·65	3·28	38·7	0·557	1·827	11·24	36·87	2·69	34·17	3255	54·
2	10·35	0·89	4·49	46·5	0·763	3·426	9·59	43·07	5·04	38·03	1612	26·1
3	14·55	1·18	5·96	86·7	1·013	6·037	13·54	80·7	8·88	71·82	1907	31·
4	16·4	1·56	7·88	129·3	1·34	10·56	15·06	118·7	15·52	103·28	1811	30·
5	17·8	1·77	8·94	159·2	1·52	13·59	16·28	145·6	19·98	125·6	1811	30·2
6	19·3	2·05	10·35	199·7	1·76	18·22	17·54	181·5	26·78	154·7	1845	30·7
7	19·6	2·06	10·40	203·8	1·77	18·41	17·83	185·5	27·04	158·5	1800	30·

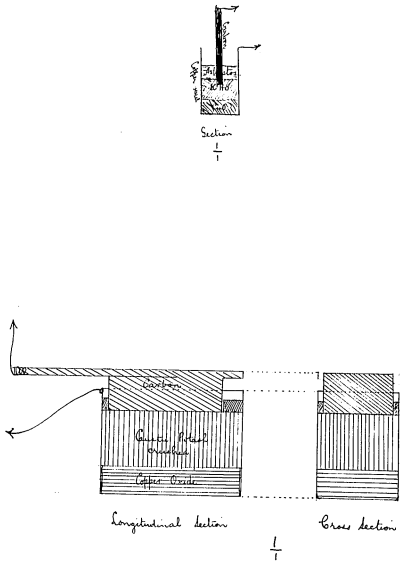


Test of Efficiency of Crocker & Wheeler
1/4 HP. low-volt series motor.

The weight of this motor is 29 lbs, 8 ~~ounces~~ and its armature 0.25 ω (hot) is in series with its field 0.17 ω (hot). The following results were obtained :-

Revs. per min.	Revs. per sec.	Scale Reading.	Torque in gm.	Energy delivered	Calculated friction		Efficiency	Remarks.	
3255	54.25	–						Running light + disconnected	
1612	26.84	500 ⊙ 23	1150	19.0	19.03		0.4085	Connected to dynamo armature	
1907	31.8	{100 ⊙ 5 500 ⊙ 20.3}	1515	29.7	42.1		0.4884	" " "	- field excited
1814	30.23	{100 ⊙ 25 500 ⊙ 21.5}	2675	68.5	34.8		0.53	load applied	
1814	30.23	{200 ⊙ 20 50 ⊙ 12}	4600	85.76	39.8		0.539	–	.
1845	30.75	{200 ⊙ 20 50 ⊙ 20.3}	5760	109.2	45.5		0.547	–	–
1800	30.0	{200 ⊙ 20 50 ⊙ 20.5}	5925	109.6	48.9		0.538	After one hour	

Temp: on the armature rose to 40°C, after the hour run.



Test of a new Thermo-Electric Element

17th October 1820.

A small copper cylinder about 2 cms long and 1 cm in diam. closed at one end was used as one plate of the cell, into the bottom was poured some coarsely powdered Calamine (battery) copper oxide. Above this some crushed caustic potash. Into this layer of potash a small stick of carbon was introduced, supported by a disk or cover of asbestos. The carbon stick formed the other pole of the cell. The resistance between the outer and inner pole was about 20000 w by bridge. A powerful blowpipe flame was then applied to the cell. Connecting the terminal to the potentiometer the first emf detected was from the carbon externally to the copper. As the temperature of the cell increased, this emf diminished, passed through zero and became reversed, the copper now being positive external to the carbon, so that the carbon took the place of zinc in an ordinary battery. At a bright red heat, the emf so observed was 0.33 volt not quite steady.

Repetition of this test on 20th October.

The cell represented on the opposite page was here tested. The same general phenomena presented themselves namely a normal cold res. of 500 w, an emf on heating diminishing vanishing and reversing. When the carbon was red hot and the caustic potash boiling over, the emf observed reached 0.67 volt at which time it gave a steady current through leads and Steinens tom galvo (1.5 w cst) of $65° = \frac{2.0146}{7.66} = 0.29$ amp. from which the int: res: would be 0.8 w. This current was observed for about 15 seconds. On again taking the emf it was found to have fallen to 0.24 volt above which value it did not again rise. This fall in emf may have been due to thermo-electric changes in the cell or chemical alteration of the surfaces. The resist. measured in the cell by potentiometer was 10 w. The galvo: indicating $22° = \frac{0.409}{7.66} = 0.053$ amp $\doteq 3.5$ w. int: res: The readings were all unsteady.

On the best value of the Standard 0.01 w.

These values of the 0.01 w are not reliable enough. The left may be nearer the truth. See p. 163 III

The original determination 7. II. 89 (I. 82.) was 0.00982
Legal w @ 16.5°C. or @ 0°C. 0.009785

next 18. VI. 89 (I. 135) was 0.009833
Legal w @ 23.5°C or 0.009784

next 20. VI. 89 (III. 144) was 0.009825
Legal w @ 24.5°C or 0.009774

Mean @ 0°C. 0.009781

On the best value of the 2000 amp. Shunt, L.w @ 0°C.

On the first good determination 18. VI. 89 (I. 135) 0.001627 Wt 2.0355. 0.001619
next 21 X 90 (2. 144) 0.001620 Wt 3.022 = 0.001613
0.001626 = 1.0 2.25. 0.001626

General mean 0.001617 w @ 0°C all in terms legal ohm

Standard = 1.00028 ω @ 16.9°C.
23
1.00258

24.5
7.6 × 0.03 = 0.23

1) $\frac{100 \times 6760}{6860} = 98.52$ ω.

$\frac{0.009867 \times 6760}{6808} = 0.009799$ @ 24.5°C. × Log. 10
$= 0.009825$ @ 24.5°

2) $\frac{15 \times 6760}{6775} = 14.97$ ω

$\frac{14.97}{9400} = 0.001592 \times 1.00258 = 0.001596$

3) $\frac{1800 \times 6760}{8560} = 1421.5$ ω

$\frac{1421.5}{1421.5 + 7078 + 2.4920} = 0.001672 \times 0.9825 = 0.001643$

4) $\frac{6760}{6760 + 24.920 + 7557} = \frac{6760}{3924.247} = 0.001722 \times 0.9825 = 0.001692$?

Comparison of Standard Resistances previous to a conductivity measurement.

24th October 1820

No. of Obs.	Temp. of Std. Res.	Res. of Std. Temp.	Temp. of Wire	Resist. of Cylinder	Ratio	Corrected Ratio	Res. of 0.01		Res. of 0.01 at 0°C	Temp. at which correct	Coeff.	Weight	Mean
1	24.5°C	1.00258	24.5°	6760	0.010	0.009774	0.009825		0.009774	107.0°	1.00021		
2	24.5°	1.00258	24.5°	6760	0.0149	0.001592	0.001596					(2)	
3	24.5	0.009825	24.5	6760	0.001672	0.001644	0.001643	0.001644	0.001643		1.00021	(2)	0.001644
4	24.5°	0.009825	24.5°	6760	0.001722	0.001692	0.001692					(1)	

Measurement of Conductivity and Tenacity of a sample of Silicon Bronze Trolley wire

The weight of a short length was first taken

No. of Obs.	Length of sample	Weight oz.	grains	Weight grammes	grammes per cm.	grammes per mile	lbs. per mile	grammes per c.c.	Sp. g.	Lbs per ft.
1.	80.95	7	120	198.5 7.78 206.28	2.5475	4.10,000	903.8	8.806	8.806	0.7764 = 0.17 lb.

The diameter

No. of Obs.	Diameter observed inches	Mean	v	Σv^2	Σv^2	r_1	Σv	r_2	Final Result
1	0.2392		−0.0003	9 × 10⁻⁸					
2	0.2391		−0.0002	4		0.04097 × 10⁻⁴		0.01242 × 2v	
3	0.2391		−0.0002	4					
4	0.2390		−0.0001	1					
5	0.2393		−0.0004	16					
6	0.2392		−0.0003	9					
7	0.2389		0						0.2389"
8	0.2391	0.23890	−0.0002	4	120	0.4663 × 10⁻⁴	0.0038	0.0000471	± 0.00005"
9	0.2386		+0.0003	9		±0.00005		0.00005	(0.60680 cm ±0.00012)
10	0.2388		+0.0001	1					
11	0.2386		+0.0003	9					
12	0.2382		+0.0007	49					Cross section 0.04483 sq. in.
13	0.2386		+0.0003	9					
14	0.2389		± 0	1					0.2988 cm
15	0.2390		−0.0001	1					
16	0.2390		−0.0001	1					
17	0.2387		+0.0002	4					

Specific Gravity by Direct Measurement (Fragar & A)

for 2 more see next page

Weight in air 12.3281
" water 10.9523
1.3758 temp. of water 24°.
× 0.99727 = 1.3724 = 8.940

$2707 + 2955 = 5662 \div 2707 = 2.092$

$2707 + 1590 = 4397 \div 2707 = 1.6242$

$2707 + 1020 = 3727 \div 2707 = 1.377$

$2707 + 220 = 2927 \div 2707 = 1.0813$

$5940 + 2707 = 8647 \div 2707 = 3.195$

$615 + 2707 = 3322 \div 2707 = 1.227$

Tests of Sample of Silicon-Bronze Trolley Wire contd.

(165)

Three lengths were measured from a fixed mark by tape line.

No. of Wire	Length by tape line 1st kind	Length by tape line 2nd kind	Length by tape line 3rd kind	Mean	v	v^2	Σv^2	$\sqrt{\ }$
1	1402.1	1402.5	1402.6	1402.4	0.3 -0.1 -0.2	0.09 0.01 0.04	0.14	± 0.10
2	1089.9	1090.2	1090.25	1090.09	0.2 -0.1 -0.1	0.04 0.01 0.01	0.06	± 0.068
3	924.0	924.15	924.2	924.07	0.07 -0.08 0.01	0.0049 0.0064 0.0001	0.0238	± 0.040
4	724.5	724.7	724.7	724.63	0.13 0.07 0.07	0.0169 0.0049 0.0049	0.0267	± 0.045
5	355.4	355.45	355.45	355.43	0.03 0.02 0.02	0.0009 0.0004 0.0004	0.0017	± 0.011
6	136.0	136.0	136.1	136.03	0.03 0.03 0.07	0.0009 0.0009 0.0049	0.0067	± 0.023

Galv. D. B. Differential 1+1 B. checked. Res. 2707 ω per coil
150 ω set with ωs: hand coil for balance.

No. of wire	Length	Res: added	to	Ratio	Standard	temp.	Res: of std	Res: of wire ω	Res: per cm ω	Resistivity
1	1402.4±0.1	2955	wire	2.092	0.01	22°C.	0.00980 (0.00980-57)	0.020502 (0.020502-57)	14.621 (14.621-3)	4224 3872 4.2011
2	1090.0±0.07	1690	"	1.6242	-	-	-	0.015842 (0.015842-65)	14.600 (14.600)	4224.6 4224.7
3	924.1±0.04	1020	-	1.377	-	-	-	0.013495 (0.013535)	14.605 (14.645)	4223.5 4235.6
4	724.6±0.05	220	-	1.0813	-	-	-	0.010600 (0.010603)	14.625 (14.667)	4229.3 4247.4
								Mean	14.658	
								Res per mile	2.358 ω	
5	355.4±0.4	5940	-	3.195	0.00163	-	0.00163	0.005207	14.650	4236.5
6	136.0±0.02	615	-	1.227	-	-	" "	0.002000	14.710	4253.8

Mean Resistance of strip 2000 amp. by this $\frac{0.001163 \times 14.615}{14.680} = 0.001620$ @ 22°C.

No. of wire	Resistivity	Mean	v	v^2	Σv^2	$\sqrt{\Sigma v^2}$	$0.1947\sqrt{n}$	Result	Resistivity of copper @ 20.5°C.	% Cond.
1	4224.8 (4.2011)	4226.35 4.238.5	-1.65	2.722	22.610	4.76	±0.927	4226.4±0.9 4235.5±0.9	17524	41.5 41.37
2	4224.6 (4.2016)		+1.75	3.062						
3	4223.5 (4.2356)		+2.85	8.123						
4	4229.3 (4.2474)		-2.95	8.703						

∴ True result probably within limits 0.001927

Specific Gravity Measurements by Frazar. temp Water 24°C.

Trial No.	Weight in air	Weight in Hg. dist.	Loss.	Sp. gr. of water (distilled)	Sp. g.	Mean Sp. g.	Weight per cm³ gms.	Wt per ft gms.	Wt per mile gms.	
1	12.3281	10.9523	1.3758	1.3795	8.940	8.941	2.586	78.78	46,100	
2	12.3281	10.9523	1.3758	1.3795	8.940					
3	12.0217	10.6808	1.3409	1.3445	8.942			0.1737 lbs	917.2 lb	

Tests of Silicon Bronze Trolley Wire

Breaking Strain. This was determined by pulling up a piston in a cylinder filled with oil. The pressure was observed on a pressure gauge and also by an indicator area of piston 77.056. Two trials. Both resulted in fair fractures, between loops

First reading	39 lbs. on gauge	37 on indicator	2850 lbs	63,610 lbs per sq. in.
Second -	45 - - -	41 . -	3160 -	70,480

Three trials were then made of ductility:—

1st gave	12 twists in 12 inches	or 3.5 per inch	
2nd -	13 - - 6	. 2.2 - -	
3rd -	18 - - 5	. 3.6 - -	

The last specimen was from a piece that had undergone the breaking stress. ※

Measurement of radius of moon's corona 22nd Oct. 90

At 19.20 the mean distance in arc from the moon center to the mean coronal circle measured 21½° by sextant. Night very calm, but misty.

Measurement of the refractive index of liquid bimesmine for the D line

The angle of the prism = 58°. 53'. 5"

. angle of minimum deviation = 42°. 27. 20"

$$\therefore \mu = \frac{\sin \frac{1}{2}(101^\circ + 17'.25'')}{\sin(29^\circ.26'.32'')} = \frac{\sin(50^\circ.38'.43'')}{\sin(29^\circ.26'.32'')} = \frac{0.7732}{0.4918}$$

$$= 1.573 \quad \text{Temp. } 23^\circ C$$

With another prism filled with distilled water

The angle of minimum deviation = 22°. 50'. 0"

- - prism = 59°. 22'. 0

$$\mu = \frac{\sin \frac{1}{2}(82^\circ.12'.0'')}{\sin(29^\circ.41'.0'')} = \frac{\sin(41^\circ.6')}{\sin(29^\circ.41')} = \frac{0.65738}{0.49321}$$

$$= 1.3275 \text{ for D. line @ } 20^\circ C.$$

※ Third test of breaking stress 20th Nov. 1820 gave following result. Same conditions as above fair break, pressure gauge 40 ; Tabor indicator 42 . Taking 41 lbs. 41 × 77.06 = 3160 lbs. pull = 70,480 lbs. per sq. in.

Revision of wire guages needed for the Milwaukee Railroad Model

Corrected for Scale Error.

The scale of the map is 600 ft to 1". or 1 mile of 5280' is 8.8"

The resistances per foot of the experimental sizes of wire are —

No. of wire	C Mils	Doubled for models	Res. per foot	Res. per foot of doubled	Res. per mile	Res. per mile doubled wire	Res. of models wire per foot	Diameter C. mils	Best size	Diam.	C mils
1	390,625	781,250	2.688×10^{-4}	1.344×10^{-4}	1.4195×10^{-3}	7.1×10^{-4}	7.1×10^{-3}	9.62×10^{-3}	10,330		
2	250,000	500,000	4.20 "	2.10 "	2.218 "	1.109×10^{-3}	1.109×10^{-3}	0.01512	6614	# 23	0.0225	625"
3	180,625	361,250	5.81 "	2.905 "	3.069 "	1.535×10^{-3}	1.535×10^{-3}	0.02093	4778	# 24	0.022	484
4	144,000	288,000	7.29 "	3.645 "	3.850 "	1.925×10^{-3}	1.925×10^{-3}	0.02625	3809	# 25	0.020	400
5	115,000	230,000	9.13 "	4.565 "	4.821 "	2.410×10^{-3}	2.410×10^{-3}	0.02886	3464	# 26	0.018	324
6	56,000	112,000	1.875×10^{-4}	9.375 "	9.90 "	4.95×10^{-3}	4.95×10^{-3}	0.0675	1485	# 30	0.0120	144

On the completion of this model, the fall of potential at the end of National Avenue was almost 25%, while at the end of the other long avenue it was generally about 20.

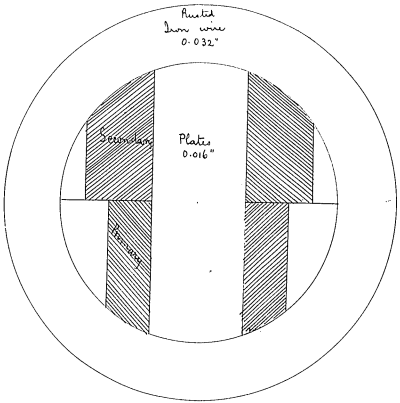
On a determination of the best size of wire to employ with a double-cotton covering on an experimental armature with deep grooves but on the same general dimensions as that detailed on p. 132.

The breadth of solid core to be 1" as before, the depth of grooves to be 3/8" 0.375, and the breadth 0.2254" as before. The free winding breadth allowing for body insulation = 0.1854" and the free depth 0.360". Two wires to one layer = 0.0368" each covered or with 0.011" collar 0.0225" say # 23 B.W.G. or 6225 c. mils. There would be 10 layers or 0.360 deep. The res. would be $\frac{8}{25}$ = 3.2 ω. Number of turns per block 50. Commutator bars 42 as before 2100 turns in all. The weight of wire on the present armature being 15 oz. Then will be $\frac{625}{256}$ = 2.5 × 15 = 38 oz. and the whole armature will weigh about 10 lb.

4

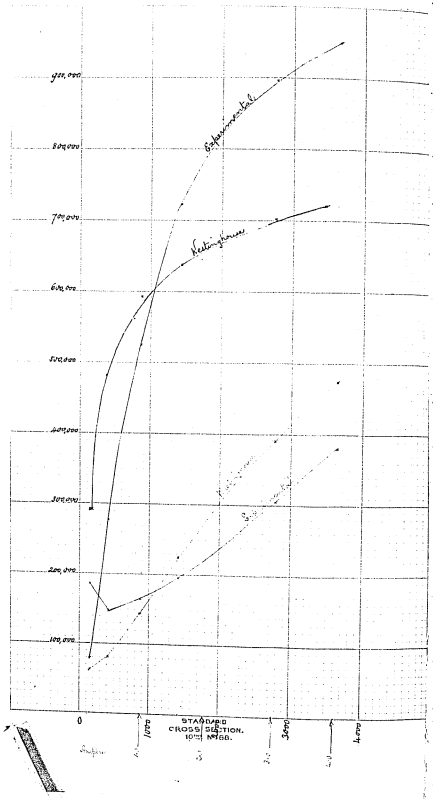
Full size

Cross section



Length of cylinder	20.4
. over wire	27.

Weight of primary		2.75 lbs.
. . secondary		3.44 .
		6.2 .
. . iron		39.
Total . .		45.2 .



Test of Edison Experimental Transformer #4.

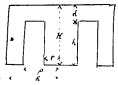
(143)

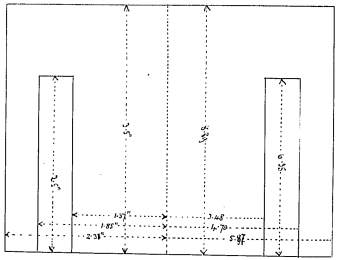
22nd October 1820.

Primary 720 turns Secondary 35

No of Hr	EMF Source	EMF	Capacity	Q	Mean Power	q per div.
	3 C. Cell. @ 22.5°C	4.29×10^{1}	$1\,9 \times 10^{-15}$	4.29×10^{-7}	168.6	2.56×10^{-9}

No	Stat. G.	Tan.	Obsch.	Amperes	M.M.F	No. of Turns	Means	Resistance	l. of G. ect	ϕ	$\frac{M}{\phi}$	
1	12°.15'	0.21712		0.1637	1458.2	4	72	25,000	30,250	79,640	1.86×10^{-3}	Experimental
2	31°.5'	0.6028		0.4546	4115	3	252	–	"	278,800	1.476	
3			0.190	0.959	868.2	2	260	50,000	55,250	525,300	1.653	
4			0.310	1.565	1417	4	187.5	100,000	105,250	721,800	1.961	
5			0.600	3.030	2743	3	233	"	"	896,600	3.059	
6			0.790	3.990	3612	4	247	"	"	957,700	3.799	
1	15°.10'	0.27107		0.2044	185	4	145	50,000	55,250	293,000	6.312×10^{-3}	Westinghouse
2	30°	0.57735		0.4357	394.1	4	229	"	–	483,000	8.158	
3	51°.30'	1.25717	0.190	0.859	862.5	3	294	"	–	594,100	1.452×10^{-3}	
4			0.316	1.596	1445	3	166	100,000	105,250	638,800	2.262	
5			0.60	3.03	2743	2	182.5	–	–	702,200	3.905	
6			0.75	3.79	3431	3	187.5	–	–	721,800	4.753	





Volume of Magnet 59.7 cubic inches
978 c.c.

" " Winding Space 12.14 cubic in.
200 c.c.

" " Weight of wire 2¼ lbs
1000 gms.

" " wire 47.56 c.i.
778 c.c.

Weight of wire. 14.25 lbs.
" " 6070 gms.

" " magnet 16.5 lbs.
" " 7070 gms

Surface of pole 58.97 sq. in.
38.05 sq. cms

" " tube 5.90 sq. in.
" " " 38.1 sq. cms

lbs. weight per sq. in. 169.5

Density in pole surface 17,300

Problem:— To determine the best dimensions of a tubular electromagnet that will give a certain lifting power with the minimum of weight.

Let s be the surface of the pole necessary for the required pull.
σ - - specific gravity of wrought iron
v - - volume of winding space necessary.
and the other dimensions as shown
W - - total weight of the magnet.

Then
$$s = \pi r^2 = \pi (R^2 - \rho^2) = 2\pi r d \qquad (1)$$
$$v = \pi h (\rho^2 - r^2) \qquad (2)$$
$$W = \sigma \{ \pi (h+d) R^2 - v \} + k \qquad (3)$$

and substituting
$$R^2 = \frac{s}{\pi} + \rho^2$$
$$= \frac{s}{\pi} + \frac{v}{\pi h} + r^2$$
$$W = \sigma \left\{ \frac{\pi (h+d)\left(\frac{hs}{\pi h} + v + h\pi r^2\right)}{\pi h} - v \right\} + k$$
$$\frac{dW}{dh} = \sigma \left\{ \left(\frac{d}{h^2}\right)(hs + v + h\pi r^2) + \left(\frac{h+d}{h}\right)(s + \pi r^2) \right\}$$

For a minimum
$$\frac{h+d}{h}(s+\pi r^2) = \frac{d}{h^2}(hs + v + \pi h r^2)$$
$$h(h+d)(s+\pi r^2) = d(hs + v + \pi h r^2)$$
$$h\pi r^2 + h^2 s + hds = hds + dv$$
$$h = \sqrt{\frac{dv}{s+\pi r^2}}$$
$$= \sqrt{\frac{dv}{2\pi r^2}} = \sqrt{\frac{v}{4\pi r}}$$

Allowing 170 lbs per sq. in: of polar surface, for a total lift of 2000 lbs we need $\frac{2000}{2\times 170} = 5.88$ sq. in:
for which the diameter $= 2.7$ in.

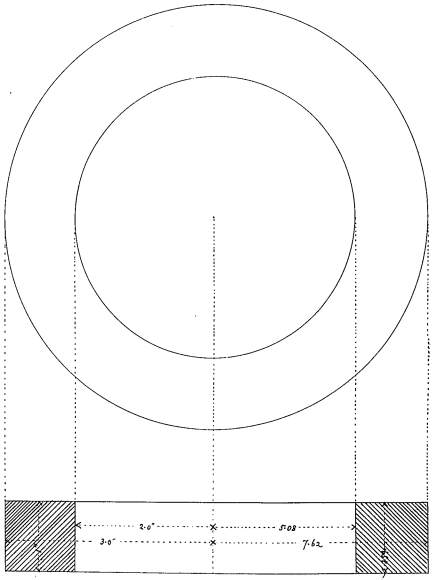
The weight of copper = say 5 lbs. = 27.5 cub. in.
$$h = \sqrt{\frac{27.5}{12.57 \times 1.37}}$$
$$= \sqrt{1.599} = 1.26'' \text{ say } 1.5''$$

Say 1 coils h = 5.5 cubic in. =

Then $\rho^2 - r^2 = \frac{27.5}{1.5} = 18.3$

$\rho^2 =$

Full size plan and diametrical section of test ring transformer



Outer circumference 18·85", 47·8g. Inner circum. 12·57", 31·92. Mean 15·71", 3

Size of iron wire in core # 28 B.W.G. 0·032" 0·0813

31 Turns per layer 31 layers. 968 turns in all.

Thickness of rust estimated 0·00075". 0·0019

Diameter of iron in wire 0·0305". 0·0775

Area of wire 0·00801 □" 0·05167 □cm Area of iron in wire 0·00731 □in 0·0471

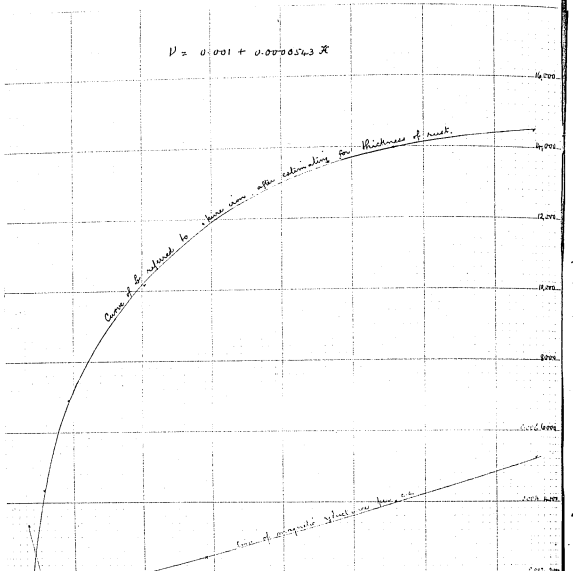
Factor of reduction. 0·9092 Total area of iron wire 0·7982 □in 5·020

Total area of iron 0·7073 □in, 4·563 □cm. Cross section of core 1·4 □in

Factor of tot. reduction. 0·707 Volume of core 15·77 cubic inches 257

Volume of iron wire 12·23 c.i. 200·4 cc Volume of iron 11·11 c.i. 182·1

Observed weight 3 lbs 3 g = 1445·5 Sp g. of wire 7·212 Mean Sp.g. of core 5·616



Tests of the Ring Transformer represented on the opposite page (50)

24th October 1820.

Two coils are wound upon this ring as shewn:-

1st 580 turns of #23 BWG. 0·025" = 0·064 cm. 215·8 in length 6552 mm averaging 0·3707' or 11·3 cms per turn, the weight being 6·75 g. or 191·4 gm. = 0·00196 lbs per ft.

2nd 108 turns of #16 BWG. 0·065" = 0·165 cm, 40·0' in length 1219 cm. averaging 0·3705 or 11·29 cm. per turn, the weight being 5·5 g. or 156 gm = 0·00359 lbs. per ft.

Capacity	Source of EMF	Value of EMF	Q	Mean Throw	Q per div.	No. of Throws
1 μ	3 C.C. @ 23°C	$4·287 \times 10^{8}$	$4·287 \times 10^{-7}$	167·25	$2·563 \times 10^{-9}$	6

Mag. No.	Std. G.	Bench.	Tan.	Ampere	MMF.	No. of Throws	Mean Throw	Res. in ecl.	Res. of g. ecl.	Φ	$\frac{\Delta\Phi}{\Delta i}$	$\frac{\Delta\Phi}{\Delta i}\left(\frac{\Delta i}{\Delta H}\right)$
1	12°·55'		0·2293	0·1729	126·1 3·161	4	68·5	–	5250	42,65	935	
2	22°·00'	~~0·103~~	0·4040	0·3047	222·2 5·571	5	55·6	25,000	30,250	19,960	4374	1·27
3	34°·30'	0·103	0·6873	0·5183 0·507	369·7 9·271	4	87·6	"	"	31,450	6894	1·345
4	56°·15'	0·221	1·4966	1·129 1·111	810 22·31	3	129·3	"	"	46,410	10,170	1·997
5	64°·45'	0·312	2·1203	1·599 1·573	1148 28·78	4	151	"	"	54,210	11,880	2·423
6	74°·	0·505	3·4874	2·63 2·55	1860 46·63	4	172·6	"	"	61,960	13,580	3·434
7	76°·15'	0·605	4·0867	~~3·083~~ 3·055	2229 55·86	5	177·5	"	"	63,710	13,960	4·001
8	80°·0'	0·82	5·6713	~~4·277~~ 4·140	3019 75·7	3	184	"	"	66,060	14,480	5·228

Resistance and Inductance of coils.

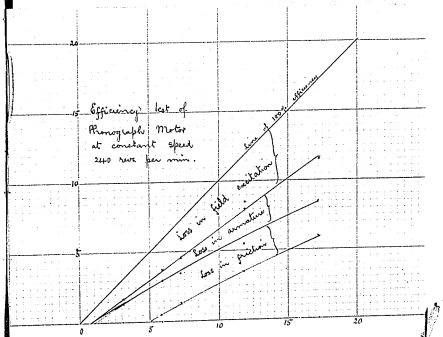
Coil #	Bridge Ratio	Coeff.	Resistance unplugged	Res.	Fund.	Tun. Res. @ 23°C.	Inductance Quadrant	Inductance Kilometric	Mutual Quadrant	Indi. Kilometric	$\sqrt{L_1 L_2}$	Acceptd. Resultn. Kilometric
1	$\frac{10,000}{100}$	0·84	21·50	0·215	0·09	0·122	0·1806	1,806 (Brass)				18·06
2	$\frac{14,000}{100}$	0·063	7361	73·61	70·09	3·52	4·637	46,370				
3	$\frac{18,000}{100}$	0·195	2363	23·63	20·09	3·54	4·6080	46,080	(Brass)			46·33
4	$\frac{18,000}{100}$	0·3[illegible]	1363	13·63	10·09	3·54	4·6610	46,610				
5	$\frac{10000}{100}$	0·371	13625	13·625	10·09	3·535			0·3912 0·4287	3912 4287	2·9092	42·5
6	$\frac{10,000}{100}$	0·308	13625	13·625	10·09	3·535						

Inductance by discharge test.

No. #	Coil	Std. g.	Tan.	Amp. Div. m	No. of Throws	Mean	Mean + accepted	res. of g. ecl.	a	$\frac{\pi y}{c}$	L Kilometric
1	Brass			0·0715	10	0	4?	5250	$10·26 \times 10^{8}$	$7·53 \times 10^{8}$	75·3
2	Fine	28°·20'	0·084 0·543	0·01409 0·014895	9	139	145 139	52,250 "	$37·16 \times 10^{8}$ $35·63 \times 10^{8}$	$4·76 \times 10^{8}$ $4·57 \times 10^{8}$	476 457

There was a spark visible at the contacts on every discharge. The key contacts were set very close, and the release made as sharp as possible. The result with the fine wire coil is remarkably close to the secohmeter measurement.

No. of Obs.	P.D. on Motor in volts	Amperes per motor	Energy taken by motor	Current thro' field in amperes	Energy taken by field	Current thro' armature in amperes	Energy in armature	Full of fet. in armature	Counter emf in armature	Loss of energy in armature	Total loss of energy
1	1·52	2·914	3·101	0·861	1·309	1·179	1·792	0·277	1·243	0·326	1·635
2	2·0	2·904	5·808	1·133	2·266	1·771	3·542	0·416	1·584	0·737	3·003
3	2·15	3·358	7·218	1·218	2·618	2·140	4·600	0·503	1·647	1·076	3·694
4	2·50	4·722	11·805	1·417	3·504	3·305	8·301	0·777	1·723	2·569	6·173
5	3·16	5·460	17·260	1·791	5·659	3·669	11·609	0·862	2·298	3·163	8·820
6	3·60	5·504	19·820	2·040	7·344	3·464	12·476	0·814	2·786	2·820	10·164
7	2·62	4·671	12·240	1·485	3·890	3·186	8·350	0·749	1·871	2·386	6·276



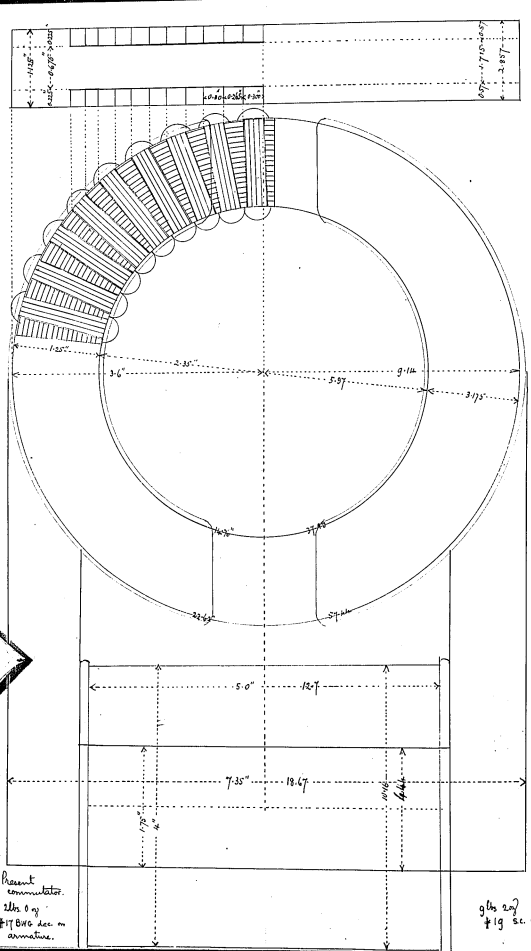
# of revs. in number	Total loss of energy
3.326	1.635
1.737	3.003
1.076	3.694
2.569	6.173
1.163	8.820
2.820	10.164
2.386	6.276

Efficiency test of the Phonograph Motor.

This motor is one that was made at the Factory taken at random and used to run a commutator. The resistance of its four field coils in series (warm) was 1.765 ω, and of its armature between brushes 0.235 ω. These standard resistances are 1.8 ω and 0.250 ω respectively. It was mounted on the float so that its axis ran horizontally, and following are readings

Total calculated useful energy	revs. per min	revs. per sec.	Scale Rly	Torque	Energy delivered	Friction	% of Eff.	Armature emf per sec	Remarks
1.466	235	3.917	50 @ 0					0.39	Armature running light
2.805	244	4.066	50 @ 2.7	.135	0.826	2.479	5.61	0.395	Coupled to dynamo
3.524	248	4.133	50 @ 7.0	.350	0.892	2.632	12.36	0.396	dynamo field excited
5.632	232	3.867	50 @ 22.	1.100	2.622	3.010	22.2	0.405	Loaded
8.440	250	4.167	50 @ 31.3	1.565	4.020	4.420	23.29	0.351	"
9.656	285	4.750	50 @ 31.2	1.563	4.079	5.077	23.10	0.356	After one hour
5.964	240	4.00	50 @ 28.4	1.420	3.502	2.462	28.62	0.368	" "

After one hour run the temperature on the armature was 79° F. The e.m.f generated for 1 rev. per sec. in the armature is say 0.4 volts. The speed at which the phonograph runs may be set at 110 revs. per min = 1.83 per sec. and the velocity ratio of the cylinder to the motor is $\frac{4.375}{2}$ = 0.6875, so that the velocity of the motor = 160 revs per min. = 2.7 per sec, and the emf 1.08. With 2.4 volts on the field the current = 1.205 amp., and the total average current being 2.3 amps. leaves 1 amp. in the armature = loss of 0.25 Watt. Total loss = (0.25 + 3.13) = 3.38 Watts, + delivered to motor 5.52 electrical efficiency = 2.14/5.52 = 38.76 %. The motor friction alone would be 1.1 Watts and the mechanical efficiency becomes 1.04/5.52 = 0.188



On the Electromagnetic design for a new model Phonograph Battery Motor of high Efficiency.

Data. The motor is to operate with governing margin on four Leclanché cells, and at a speed 50% in excess of that in the existing type, the external diameter being preserved. The energy to be utilised in motion is 2 Watts.

The emf of one Leclanché cell is after service 0.65 volts so that the emf of the battery is 2.6 volts. 1.2 amps flowing through its resistance (0.05×4 = 0.2) gives a drop of 0.24 volt and 0.06 in the leads gives an emf at m.t. of 2.3 volts. It is necessary therefore that for governing margin the emf generated by the motor must be 2.0 volts.

The present rotating speed is 160 revs. per min, so that we have for the given speed 2400 revs per min = 40 per sec.

$$\therefore \quad 4\,\phi w = 200,000,000$$

$$\phi w = 25,000,000$$

Let $w = 480$

$$\phi = 52,100$$

With $b = 10,000$ this gives 5.21 sq. cms. of cross section. The cross section allowed is 1.715 × 3.175 = 5.447 and with 4% pipe 5.2. The mean turn is 4.6" = 0.39 say 0.4' and 480 turns = 192'. The wire adopted is #17 BWG. 0.058" cond. to 0.070" in 40 grooves of 4 layers 4 wire wide. The res. of this wire per foot = 0.00307 ω. Res. of armature = 0.15 ω. The fall of pot: with one amp. through this is 0.15 volt or 7.5% of 2 volts. The energy lost 0.15 Watt. The breadth of groove = (4×0.070"+4×0.05") = 0.300", of the space (0.265"+0.05") (0.473 − 0.175).

The clearance is to be 0.03" on each side = 0.076 cms. The total air length 0.152. The mean polar area of iron is 1.3146 sq. cms × 16 × 2 = 43 sq. cms, so that the reluctance of the air gap is 0.00353. The reluctance of 15 cms of armature 5" in area = $\frac{3}{4}$ × 0.0005 = 0.00075 and 20 cms of field magnet 15 sq. cms in area = $\frac{20}{3}$ × 0.0005 = 0.0016, so that the total reluctance is 0.0059 lines. To drive 104200 lines through this requires 615 MMF = 489 say 500 A.T. allowing ½ of one ampere in the field circuit = 2500 turns.

For 15 sq. cms of magnet section 4.37 diam is needed = 1.75". The mean turn = 0.8'. ∴ total length = 2000 feet. This has to offer a resistance of 10 ω = 200' per ω. #19 BWG. nearest. = 9.124 lbs. of field wire. This will occupy 50.2 c.i. or with a core 5" long 10 sq. in. The area of the core being 2.405 sq. in + 10 = 12.405 = 4" diam.

With 2.0 volts at m.t. and 1 amp. passing through the armature 0.2 through the field, the energy absorbed = 2.4 Watts. The power in the field is 0.4 and in the armature 0.15 Watt. total loss 0.55 total useful energy 1.85 and efficiency electrical 77%. With 2 amperes in the armature the loss would be 0.3 Watt, the total 0.7, and the useful energy 4.4 − 0.7 = 3.7 the efficiency 84%.

The torque would be $\frac{480 \times 104,000 \times c}{6.28}$ = 7,846,600 × c dynes.

for 1 ampere 7,846,600 dynes = 800 grammes weight or 90 at the periphery. With 4 cells, the current would be approximately 2.6/0.4 = 6.5 amperes and the torque 5200 grammes weight or 580 at the periphery, at starting or when machine is held.

23·4
15·5
7·9 × 0·03 = 0·237 ft.

23·3
14
4·3 × 0·03 0·129 × 5 = 0·6445 = 5·00645

21·1
16·9
4·2 × 0·03 = 0·126 ft. 0·00126
1·00228
1·001514

23·3
19·0
4·3 × 0·03 = 0·129 ft. × 10 = 1·29
10·0129

21·14 × 0·388 = 8·3094 ft.
21·14 × 0·404 = 1·00644

(153)

Measurement of the Conductivity of the Iris Copper wire employed in Experiments made for determining the temperature coefficient of copper.

1st series 23rd July 20. Differential Astatic Mirror Galv. adjusted. Res. of both coils 13500 ω = 6750 ω each. Test of wire that had been used in previous experiments

No. of Obs.	Length of wire	Res. added	to	Sum	Ratio	Standard	Temp.	Res. at temp.	Res. of wire	Res. per cm.	Temp. wire
1	25·3	8313	wire	15,063	1·812	Legal ω 15°C	23·4°C	1·00237	1·816 ω	0·07177	23·4°C.
2	17·0	3777	"	10,527	1·559	"	"	"	1·563	0·09192	
3	61·95	·585	"	7,335	1·087	S. ω 15°C	23·3°	5·00645	5·4241	0·08752	
4	69·48	1490	"	8,240	1·221	"	"	"	6·111	0·08732	23·8°C
5	60·03	3245	"	7,095	1·0512	"	"	"	5·263	0·08768	23·2°C

2nd series October 20. Res. of Galv: both coils 13450 = 6725 ω each

No. of Obs.	Length of wire	Res. added	to	Sum	Ratio	Standard	Temp.	Res. at temp.	Res. of wire	Res. per cm.	Temp. wire
1	17·775	5700	wire	12,425	1·847	1·00250 N.S.	21·1	1·001514	1·8506	0·10407	22·7C
2	89·96	2150	10 ω	8875	1·320	1·00019	23·3	1·00129	0·7586	0·08430	21·4°
3	87·79	2360	"	9,085	1·351	"	"	"	0·7410	0·08440	21·4°
4											

The weight of the 17·775 cms was 0·0291 gms or 0·001637 gms per cm.
" " " 99·75 " " 0·1915 " " 0·001920 " " "
Allowing a sp. g. of 8·90 would give an area of 0·0002157 sq. cms or a diameter of 0·05214 cms or 0·002063"

0·08435 × 0·0002157 = 1820 ohs units @ 21·14°C.
= 1680 " " legal @ 15°C.
1·65 for 15°C
= 0·9666 conductivity of 16214

Galvanometer Constants

28th Oct: 20.

No. of Obs.	Deflection both sides	Substance	Weight before	Weight after	Gain	Accepted transfer	Transfer per sec.	Current	Check Deflection	Time per cm.	Time of Osc. after defl.	Damp per half-swing
1	300	Ag	12·1655 11·8732	11·7753 12·2564	−0·3902 +0·3832	0·3967	0·001289	1·1529	0·222	0·193	4·45814	0790
2	600	Cu	10·1343 9·3000	9·9067 9·5324	−0·2276 +0·2324	0·2290	0·0003216	1·1693	0·2287	0·1965	1·129149	9·7778

Measurement of the Inductances of various coils with the Leathmeter

No.	Coil	Bridge Ratio	Res: ohms	Batty.	Inductance henries	Inductance kilometres	Leads	Time res:	Temp.	Res: @ 0°C	Time Const @ 0°C seconds	T.O.
1	H.B gilling 11lb	1000/100	223.47	0.920	0.2056	2056	1.02	222.45	20.3°C.	206.25	0.000997	20.3 °C
2	10lb	"	223.77	"	0.2057	2057	"	222.75	"	206.5	0.000997	
3	121 lb	"	4416.57	1.820	0.8170	8170	-	4408.55	"	4113.1	0.000978	
4	W-b	"	4416.47	0	0	0	-	4405.85	"	4113.35		
5	p/w + b-wire	"	224.27	0	0	0	—	223.25	"	207.0		
6	bunch	1000/1000	224.20	2.790	0.2100	2100	-	223.28	"	208.0		
7	H.B gilling 100 lb	1000/1000	1248.1	0.1340	0.1747	1747	1.02	1247.1	"	1157.3	0.000157	19.5
8	" " b	"	2308.1	0.220	0.5475	5475	"	2427.1	"	2308.0	0.000237	"
9	Inductionless coil 12Ω	1000/5	13.135	1.5358	0.02016	201.6	1.00	12.135	19°C.	12.30	0.001782	"
10	Sec. of	"	"	1.1425	omitted	114.25	"	-	"	-		
11	" " "	"	-	1.6140	omitted	13.67	-	-	"	-		
12	pri	"	1.305	0.195	0.00255	25.45	-	0.305	"	0.282	0.009	

Experiment made to ascertain whether the gravitation force varied with the temperature of the attracting bodies.

Some preliminary experiments were tried on the 26th Oct. using an ordinary 18 c.p. electric lamp ~~of~~ weighed on the chemical balance and supplied with current by a pair of small copper wires dipping into mercury. No difference could be appreciated in the weight when the lamp was raised to vivid incandescence, the limit of distinct observation being 0.003 gms. The experiment was however of little value because the weight of the carbon filament was found to be only about 0.023 gms, so that a very great change in the weight would have passed unnoticed.

The experiment was repeated however with greater accuracy on the 27th with a special lamp as follows:— A special carbon lamp was made. The globe was a 50 c globe, and the filament a special carbon filament for 50 c.p. in a spiral the weight of the filament being 0.0405 gms. The diameter of the helix was 0.75 and there were 9.5 turns + 5.5 cms or 22.4 + 5.5 = 27.9 cms of filament. The cross-section was rectangular 0.0110" × 0.0075" = 0.0279 c × 0.0476 cm = 0.000133 sq

The weight of lamp and glass beaker over it (to reduce convection) was 1244.0 gms. The period of the balance for this load was 40 secs. for one double vibration. The wires first employed to make contact with the mercury in the tubes was 0.005" copper (0.0126) diam. The weight of these per cm = 1.127 mgm. or of two ~~0.0225~~ 0.00225 gms per cm. The length of the arms = 22 cms, and the length of the pointer 30.5. By using a magnifying glass, a displacement of about 0.1 mm could be detected. The mercury cups were formed of glass tubes 0.35 int and 0.45 ext. diam., bashed side by side, and upright. These reduced the period of vibration to 3 seconds.

A series of readings was made with this lamp, using a current of 1.97 amperes and 120 volts. In every case it was found that the weight diminished about 10 mgms permanently or subpermanently, after an application of the current, the lamp being brought to bright incandescence, and no change was noted at any time that could be attributed to variation in weight. The limit of appreciation was 0.002 gms, and a variation of 0.002 would certainly have been detected = 7.5%. The dipping wires were subsequently reduced to a diameter of 0.0025" 0.0065 cm, and this was the practical limit, since 0.002" or 0.005 cm, failed to carry the current. The following is a sample of the observations:—

21.11.20 Weight balancing 1244.0150

12.00 Current on. pointer at zero

.15 - off. pointer 0.002 say or half the breadth of zero line displaced in direction indicating less weight.

13.00	- - - - -	0.004 cms or whole breadth
13.30	- - - - -	0.004
14.00	- - - - -	0.003
14.30	- - - - -	0.002
15.00	- - - - -	0.002

Balanced afresh by 1244.000.

Traction Calculations.

Required the power and force to carry
20 trucks each 30 tons in weight (loaded) up a 1.5% gr. 5 mph.
" " " - - - - - 0.5% gr. 15 m.p.h.
" " " - - - - - level 15 . . .
the weight of the engine being estimated at 100 tons.

Total weight 1000 tons or 2000,000 lbs. 1.5% . 30,000 lbs.
haulage 7 lbs per ton = 7000
Total pull on 1.5% grade 37,000 lbs. at driving axle.
~~This is maximum pull.~~

Power at 5 mph. = 7.33 ft. per sec. = 271,300 ft lbs. per sec.
= 493 HP.
= 368 kwts.

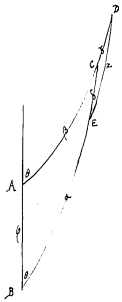
Total weight 1000 tons 0.5 % = 10,000 lbs.
haulage 7000
Total pull on 0.5 % grade 17,000 lbs. at driving axle

Power at 15 m.p.h. = 22 ft. per sec. = 374,000 ft lbs. per sec
= 680 HP.
= 507 kwts.

This is the maximum power to be exerted.
The power to be developed allowing 70% commn efficiency
= 725 kwts

With 100 volts at motor terminals = 7250 ampere
- 500 . - - - = 1450 - .

Power at 15 m.p.h. on level = 154,000 ft lbs. per sec.
= 280 HP
= 209 kwts developed
@ 70 % efficiency) this is = 300 kwts absorbed
at 100 volts @ mt. = 3000 ampere
- 500 - - = 600 .



θ

Calculation of the angle made by the tangents at any two points of a uniform helix, distant $(\varphi + 2n\pi)$ from each other, the angle of the helix being θ.

28th Oct: 20.

Let A and B be the two given points. Then projecting the great-circular arcs BEC, and ACD along the tangent lines of the helix the angle made by the two tangents will be the angle ED or x formed by the polar arcs E and D of these circular arcs respectively.

Then $\tan\left(\frac{\alpha+\beta}{2}\right) = \tan\frac{\varphi}{2}\,\frac{\cos\frac{1}{2}(2\theta-\pi)}{\cos\frac{1}{2}(\pi)} = \infty$

$\therefore\ \alpha+\beta = \pi$ or $\beta = \pi - \alpha$

but $\xi = \frac{\pi}{2} - \beta$

and $\delta = \alpha - \frac{\pi}{2}$

$\therefore\ \delta - \xi = -\pi + \alpha + \beta = 0$ or $\delta = \xi$.

while $\cos x = \cos\delta\cos\xi + \sin\delta\sin\xi\cos(\pi - C)$

$= \cos^2\delta + \sin^2\delta\cos(\pi - C)$

$= \cos^2\left(\alpha - \frac{\pi}{2}\right) + \sin^2\left(\alpha - \frac{\pi}{2}\right)\cos(\pi - C)$

$\therefore\ = \sin^2\alpha - \cos^2\alpha\cos C$ (1)

Also $\tan\left(\frac{\alpha-\beta}{2}\right) = \tan\frac{\varphi}{2}\,\frac{\sin(\theta - \frac{\pi}{2})}{\sin\frac{\pi}{2}}$

$\therefore \tan\left(\frac{\alpha-\beta}{2}\right) = -\tan\frac{\varphi}{2}\cos\theta$

or $\cot\alpha = \tan\frac{\varphi}{2}\cos\theta$

$\therefore\ \sin^2\alpha = \dfrac{1}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$

and $\cos^2\alpha = \dfrac{\tan^2\frac{\varphi}{2}\cos^2\theta}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$

Hence by (1) $\cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}\cos^2\theta\cos C}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$ (2)

$\sin C = \sin(\pi - \theta)\sin\varphi / \sin\alpha$

$\therefore\ \cos C = \sqrt{1 - (\sin^2\varphi\,\sin^2\theta)(1 + \tan^2\frac{\varphi}{2}\cos^2\theta)}$

$\therefore\ \cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}\cos^2\theta\sqrt{1 - (\sin^2\varphi\,\sin^2\theta)(1 + \tan^2\frac{\varphi}{2}\cos^2\theta)}}{1 + \tan^2\frac{\varphi}{2}\cos^2\theta}$ (3)

If $\theta = 0$

$\cos x = \dfrac{1 - \tan^2\frac{\varphi}{2}}{1 + \tan^2\frac{\varphi}{2}}$ or $x = \varphi$

If $\theta = \frac{\pi}{2}$

$\cos x = 1$ or $x = 0$

If $\varphi = 0$ $x = 0$

$\varphi = \frac{\pi}{2}$ $x = 2\theta$

Gravitation Measurements contd.— 29th Oct.

Since the limit of certain detection in the experiments recorded on page 155 was only 7.5% up to visible incandescence say 1000°C, a special lamp was constructed of platinum wire, as follows:— A platinum wire 0.0125" (0.031) in diam and 20.2" 51.3 long) weighing 0.863 gm. was coiled into a helix of 18 spires and about 0.5 diam. This was sealed in a 50 c.p. globe and the latter exhausted. Four platinum wires of equal sizes 0.0125" formed the electrodes. This lamp was supported vertically under a beaker on the scale pan, and contact made into the mercury in the previously used tube by means of wire 0.0025" 0.00645 cm. diam. and 0.5 long, soldered on to the main copper electrodes of the lamp. It was found impossible to bring this lamp up to any high degree of incandescence, as ~~it lost~~ the platinum spiral lost rigidity, and threatened to collapse. A cherry red heat however was secured without difficulty, which may be estimated at 800°C.

The weight of lamp and beaker was 131.33 gm, and when working well, it was easy to read to one milligram. The first currents used lasted 20 to 30 secs, and were 1.5 amp, requiring 15 secs. to bring filament to luminous temp. Latterly, the current was raised to 2.9 amp, at which the collapse of the spiral became imminent after prolonged application. Red heat was then reached in 5 secs. In all the trials there was a distinct movement of the pointer in the direction indicating less weight for balance, within 5 secs. of the time of applying the current, and in most cases long before red heat was attained. This continued ~~for~~ steadily during the continuation of the current, but was permanent or sub-permanent, and appeared to have no connection with the temperature of the filament.

The movement noticed was supposed to be due in the first instance to the electromagnetic repulsion between the mercury and wire, followed by convection effect. It would have been possible to detect a change of 1 mgm in the weight of the filament while 3 mgms could not have escaped notice or 0.35%. The phenomena alluded to occurred with both directions of current, alike. The applications varied from 5 to 30 seconds. This test although the temperature attained was not so high as in the preceding cases, was considered conclusive, to the limit of accuracy stated, 4%.

Feeder Determination for Cincinnati O.

C.S. at 8th St Station

Feeder No.	Running via	Length feet	Average Empties	to	Drop needed	#	Drop obtainable	Cost per ft	Cost of feeder	Cost of total feeder	Cost per amp.
I	Elm + Pearl	5550	464	377	28	1000	28.0	3.96	21,980		
	Broadway	375	87	369	2	200	1.7	1.21?	454		
	Pearl	600	158	378	2	500	2.06	2.24	1,344		
	Pearl + Congress	1380	121	379	2	1000	1.8	3.96	5,465		
	Broadway	250	98	387	2	150	1.8	1.10?	275	29,518	$63.44
II	Elm + 4th	3900	581	358	25	1000	24.8	3.96	15,440		
	Main	420	213	367	5	200	4.7	1.21?	508		
	Fourth + Sycamore	1200	252	376	5	650	5.1	2.592	3,111		
	Fourth + Broadway	1450	116	318	5	350	5.2	1.856	2,691	21,750	$7.00
III (1+2)	Garfield + Vine	3700	206	373	24.5	{1000 / 1000}	24.5	7.920	29,300		
	Pearl	480	786	374	5.5	750	5.5	2.80?	1,344		
	Pearl + Walnut	1200	420	389	5.5	1000	5.5	3.96	4,752	35,396	$34.36
IV	Garfield Race + 2nd	4250	610	383	20	1000	28.6	3.96	16,830	16,830	$37.40
V	Elm	2850	793	371	25	1000	24.9	3.96	11,290		
	Elm	300	120	381	5	100	3.3	1.00?	300		
	Pearl	450	673	372	5	650	5.0	2.592	1,167	12,757	$14.19
VI	Vine + 5th	3100	671	329	23	1000	22.9	3.96	12,280		
	Fountain Sq.	570	310	320	7	200	6.5	1.472	839		
	Walnut	450	361	357	7	250	7.0	1.344	605	13,724	$20.40
VII	Garfield + Race	2200	872	346	21.0	1000	21.0	3.96	8,712		
	Race	500	481	354	9	300	8.8	1.472	736		
	Race + Third	1350	391	365	9	650	9.0	2.592	3,500	12,948	$14.05
VIII	Garfield + Vine	2550	613	347	17	1000	17.2	3.96	10,100	10,100	$16.40
IX	Elm	1080	905	314	11	1000	10.8	3.96	4,280		
	George, Race + 4th	1200	281	308	6	600	6.1	2.48	2,976		
	Elm + 6th	750	65	304	6	100	5.3	1.00?	750		
	George + Race	700	301	315	6	400	5.5	2.00	1,400		
	Elm	650	258	345	6	300	6.0	1.472	957	10,363	$11.45
X	Ninth	1420	438	410	10.5	650	10.5	2.592	3,681		
	Ninth	960	99	274	6.5	150	6.9	1.10?	1,056		
	Vine + 6th	1500	175	317	6.5	450	6.3	2.096	3,144		
	Ninth + Main	2150	164	264	6.5	600	6.4	2.480	5,333	13,214	$20.18
XI (1+2)	Eighth + Central	1600	959	322	8.5	{1000 / 1000}	8.4	7.920	12,670		
	Central Ave	520	416	343	8.5	200	7.8	1.472	765		
	Central 5th + John	1400	543	349	8.5	1000	8.3	3.960	5,543	18,978	$19.73
XII	Central + 7th	3000	327	321	21.5	500	21.3	2.240	6,720		
	Butler + 9th	1275	147	302	8.5	250	8.2	1.344	1,713		
	Butler, 6th + Stone	1620	180	339	8.5	350	9.0	1.856	3,006	11,439	$24.48
XIII	Plum	780	316	530	9.0	300	9.0	1.472	1,148		$3.10.55
	Seventh	500	138	206	5.0	150	5.0	1.10?	550		
	Seventh	500	178	313	5.0	200	4.75	1.21?	605	2,303	$7.74
XIV	8th, Central Ave, + 9th	3700	287	301	24.75	400	27.75	2.00	7,400		
	9th + Freeman	1050	58	311	2.25	300	2.2	1.472	1,545		
	Baymiller	580	129	281	2.25	350	2.2	1.856	1,076	10,021	$24.02
		66010	8332						$219,341	219,341	

Elm + Plum St.

Feeder Estimate for Cincinnati C. S.

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Feeder No.	Running via	Length	Drop	to	Drop needed	#	Drop obtainable	Cost per ft	Cost of feeder	Cost of Total feeder	Cost per amp.
		66,010	8332								
XV	Plum 8th, Central + 8th	1425	287	531	10	450	9.9	2.096	2,987	219,341	219.341
	John + 9th	780	91	304	7	100	7.7	1.00?	780		
	John 9th + Mound	1400	80	287	7	200	6.2	1.21?	1,694		
	Eighth	600	216	532	4	350	4.0	1.856	1,114		
	Eighth + Butler	900	56	321	3	200	2.7	1.21?	1,089		
	Mound	760	160	331	3	300	2.8	1.472	1,119	8,783	$30.60
XVI	Central Park Lane + Fourth	5050	251	241	25	550	25.1	2.384	12,040		
	Baymiller + Wade	1800	89	205	5	350	5.0	1.856	3,341		
	Baymiller Laurel Freeman	920	69	243	5	150	4.6	1.10?	1,012	17,251	$62.72
XVII	9th, Central Ave.	2100	381	253	9	1000	8.8	3.96	8,315		
	Clark + Linn	2460	90	242	8	300	8.0	1.472	3,620		
	Clark	1250	173	247	8	300	7.8	1.472	1,840		
	John + Everett	1920	118	234	8	300	8.2	1.472	2,825	16,600	$42.57
XVIII	Ninth + Central	2400	143	252	15.5	250	14.9	1.344	3,226		
	Central	210	72	253	1.5	100	1.7	1.00?	210		
	Central	600	71	231	1.5	250	1.8	1.344	807	4,243	$29.46
XIX	Ninth + Elm	3420	341	213	23	550	23.1	2.384	8,152		
	Elm + Findlay	1750	136	508	7	350	7.4	1.856	3,247		
	Liberty	950	120	215	7	200	6.2	1.21?	1,150		
	Liberty + Central	1440	85	212	7	200	6.7	1.21?	1,743	14,292	$41.91
XX	Elm + 14th	3350	214	227	12.0	650	12.2	2.592	8,684		
	Elm	1050	105	213	4.8	250	4.8	1.344	1,411		
	15th, May, Liberty	1725	109	217	4.8	400	4.9	2.00	3,450	13,545	$63.79
XXI	Elm, Court, Race	2040	349	266	13	600	12.9	2.480	5,060		
	12th Vine	1170	140	265	4	450	4.0	2.096	2,452		
	Twelfth	430	201	267	4	250	3.7	1.344	578	8,090	$23.18
XXII	Elm, Court, Main, Woodward	4250	224	259	25	400	24.9	2.000	8,500		
	Woodward + Broadway	1200	87	219	5	250	4.9	1.344	1,728		
	Woodward + Hamilton	1320	52	415	5	150	5.0	1.00?	1,452		
	Sycamore + Abigail	760	85	263	5	150	4.7	1.00?	836	12,535	$55.96
XXIII	Ninth + Elm	780	266	275	9	250	8.9	1.344	1,048		
	Court	900	112	279	8	150	7.4	1.00?	990		0.5 cents at C.S.
	Court	990	78	272	8	120	7.1	1.00?	1,040		
	Court + Race	1260	76	294	8	150	7.2	1.00?	1,386	4,464	$16.78
XXIV	9th, Central, Lincoln + Baymiller	6450	348	533	25	1000	24.7	3.96	25,540		
	Poplar + Western	1100	75	202	5.3	150	5.9	1.21?	1,331		
	Baymiller	1080	54	525	5.3	120	5.3	1.00?	1,188		
	Baymiller	1650	219	516	4	1000	4	3.96	6,534		
	Dayton	1080	74	519	1.3	600	1.5	2.48	2,678		
	Baymiller	900	70	515	1.3	500	1.4	2.24	2,016		
	Dayton	650	75	517	1.3	400	1.3	2.00	1,300	40,587	$116.66
		133,160	8228						$359,731	$359,731	

6500 lts
4500 #
3370 Kurts.

$5.535 per amp.
$33.34 per amp.